Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs

FY 2004 Budget Request

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Prepared by the

National Renewable Energy Laboratory

April 2004 NREL/TP-620-36404

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

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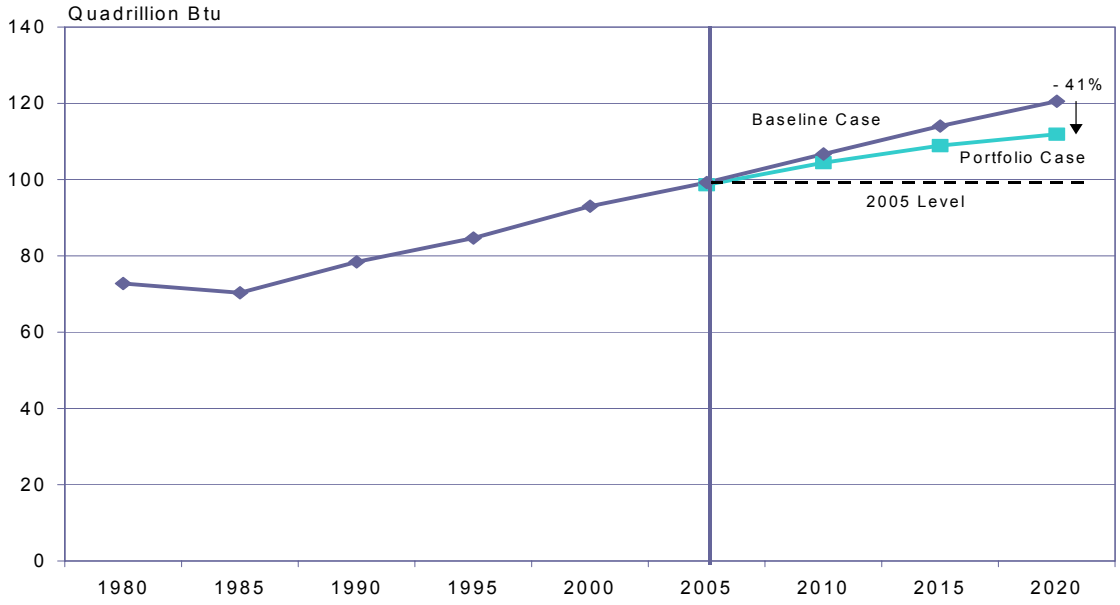

Nonrenewable Energy Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Prepared for the

U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy Programs

Prepared by the

National Renewable Energy Laboratory

April 2004
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Table of Contents

Executive Summary ES-1
Chapter 1 – Introduction 1-1
Role of Benefits Analysis in Performance Management 1-2
Benefits Framework 1-4
EERE's 2002 Reorganization 1-5
Analysis Team 1-6
Report Organization 1-7
Chapter 2 – EERE Benefits-Analysis Process 2-1
Step 1: Baseline Cases and Guidance 2-2
Step 2: Program and Market Inputs 2-9
Step 3: Program and Portfolio Benefits Estimates 2-12
Chapter 3 – FY 2004 Benefits Estimates 3-1
Outcomes and Benefits Metrics 3-1
Portfolio Benefits 3-4
Program Benefits 3-10
Chapter 4 – Benefits Analysis of EERE's Programs 4-1
Introduction 4-1
Biomass Program 4-2
Building Technologies Program 4-3
Distributed Energy and Electric Reliability Program 4-5
Federal Energy Management Program 4-9
FreedomCAR and Vehicle Technologies Program 4-10
Geothermal Technologies Program 4-15
Hydrogen, Fuel Cells, and Infrastructure Technologies Program 4-16
Industrial Technologies Program 4-17
Solar Energy Technologies Program 4-19
Weatherization and Intergovernmental Program 4-20
Wind and Hydropower Technologies Program 4-21
Appendix A – Data: Baseline and Portfolio Cases A-1
Appendix B – Building Technologies B-1
Appendix C – Industrial Technologies C-1
Appendix D – Renewable Technologies D-1
Appendix E – Vehicle Technologies E-1

List of Tables

Table ES.1: EERE FY 2004 Benefits Metrics ES-1
Table ES.2: Summary of EERE Integrated Portfolio Benefits for FY 2004 Budget Request .. ES-2
Table ES.3: U.S. Department of Energy Office of Energy Efficiency and Renewable Energy: FY 2004 Funding Summary and Selected 2020 Benefits by Program ES-5
Table 3.1: Annual EERE Portfolio Benefits for FY 2004 Budget Request for Selected Years .. 3-4
Table 4.1: Program Benefits Modeling by Primary Type of Model Used/Subprogram Area 4-1
Table 4.2: FY04 Benefits Estimates for Biomass Program (NEMS-GPRA04) 4-3
Table 4.3: FY04 Benefits Estimates for Building Technologies Program (NEMS-GPRA04) ... 4-5
Table 4.4: Distributed Energy Resources: Capacity and Generation: 2005, 2010, and 2020 4-8
Table 4.5: FY 2004 Benefits Estimates for DEER (NEMS-GPRA04) 4-9
Table 4.6: FY 2004 Benefits Estimates for FEMP (NEMS-GPRA04) 4-10
Table 4.7: FY 2004 Benefits Estimates for FreedonCAR & Vehicle Technologies Program (NEMS-GPRA04) 4-13
Table 4.8: Selected Vehicle Attributes (Year 2020, South Atlantic Region, Large Cars) 4-14
Table 4.9: FY 2004 Benefits Estimates for Geothermal Technologies Program (NEMS-GPRA04) 4-16
Table 4.10: FY 2004 Benefits Estimates for Hydrogen, Fuel Cells, & Infrastructure Technologies Program (NEMS-GPRA04) 4-17
Table 4.11: FY 2004 Benefits Estimates for Industrial Technologies Program (NEMS-GPRA04) 4-18
Table 4.12: FY 2004 Benefits Estimates for Solar Energy Technologies Program (NEMS-GPRA04) 4-20
Table 4.13: FY 2004 Benefits Estimates for Weatherization and Intergovernmental Program (NEMS-GPRA04) 4-21
Table 4.14: FY 2004 Benefits Estimates for Wind & Hydropower Technologies Program (NEMS-GPRA04) 4-22
Table 4.15: Wind Technology Assumptions 4-23

List of Figures

Figure ES.1: U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases ES-6
Figure ES.2: U.S. Total Energy Expenditures, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases ES-6
Figure ES.3: U.S. Carbon Dioxide Emissions, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases ES-7
Figure ES.4: U.S. Oil Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases ES-7
Figure ES.5: U.S. Natural Gas Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases ES-8
Figure ES.6: U.S. Renewable Electricity Capacity, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases ES-8

Figure ES.7: U.S. Renewable Electricity Generation, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases ES-9
Figure 1.1: Generalized EERE Logic Model 1-3
Figure 1.2: FY 2004 Benefits Metrics Reported 1-4
Figure 2.1: EERE Program and Portfolio Benefits-Analysis Process 2-1
Figure 2.2: U.S. Conventional Energy Demand and Energy Intensity, 1980-2000, and Baseline Projections to 2020 2-4
Figure 2.3a: Potential Impacts of EERE R&D Programs on Technology Introduction 2-6
Figure 2.3b: Potential Impacts of EERE Deployment Programs on Market Penetration 2-6
Figure 2.4: Class 4 Wind Capital Cost and Capacity Factor 2-7
Figure 3.1: U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases 3-5
Figure 3.2: Comparison of Program and Portfolio Nonrenewable Energy Consumption Estimates, 2005, 2010, and 2020 (quadrillion Btu) 3-5
Figure 3.3: U.S. Total Energy Expenditure, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases 3-6
Figure 3.4: U.S. Carbon Dioxide Emissions, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases 3-7
Figure 3.5: U.S. Oil Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases 3-8
Figure 3.6: U.S. Natural Gas Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases 3-9
Figure 3.7: U.S. Renewable Energy Capacity, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases 3-9
Figure 3.8: EERE Program FY 2004 Budget Requests (2000 dollars) 3-10
Figure 3.9: Annual Nonrenewable Energy Savings: 2005, 2010, 2020 (quadrillion Btu) 3-12
Figure 3.10: Annual Energy Expenditure Savings: 2005, 2010, 2020 (billion 2000 dollars) 3-12
Figure 3.11: Annual Carbon Dioxide Savings: 2005, 2010, 2020 (million metric tons carbon equivalent) 3-13
Figure 3.12: Annual Oil Savings: 2005, 2010, 2020 (quadrillion Btu) 3-13
Figure 3.13: Annual Natural Gas Savings: 2005, 2010, 2020 (quadrillion Btu) 3-14
Figure 3.14: Annual Renewable Electric Capacity – Energy Efficiency, DEER, and Renewables: 2005, 2010, 2020 (gigawatts) 3-14
Figure 4.1: DER Market-Penetration Function in New Buildings for 2010 4-7
Figure 4.2: DER Market Share Over Time in New Commercial Buildings 4-7
Figure 4.3: Industrial CHP Market Acceptance 4-7
Figure 4.4: Vehicle Sales Shares in 2010 4-12
Figure 4.5: Vehicle Sales Shares in 2020 4-12
Figure 4.6: Vehicle Stock Shares in 2010 4-12
Figure 4.7: Vehicle Stock Shares in 2020 4-12
Figure 4.8: Vehicle Miles Traveled in 2010 4-13
Figure 4.9: Vehicle Miles Traveled in 2020 4-13
Figure 4.10: Geothermal Supply Curve, Northwest Region 4-15

EXECUTIVE SUMMARY

The Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (DOE) leads the Federal Government's efforts to provide reliable, affordable, and environmentally sound energy for America, through its research, development, and deployment (RD&D) programs. EERE invests in high-risk, high-value research and development (R&D) that, conducted in partnership with the private sector and other government agencies, accelerates the development and facilitates the deployment of advanced clean energy technologies and practices. The RD&D activities of EERE are designed to improve the nation's readiness to address future energy needs.

This document summarizes the results of the benefits analysis of EERE's programs, as described in the FY 2004 Budget Request. EERE is adopting a benefits framework developed by the National Research Council (NRC)[1] to represent the various types of benefits resulting from the energy efficiency technology improvements and renewable energy technology development prompted by EERE programs. Specifically, EERE's benefits analysis focuses on three main categories of energy-linked benefits—economic, environmental, and security. The specific measures or indicators of these benefits estimated for FY 2004 are identified in **Table ES.1**. These measures are not a complete representation of the benefits or market roles of efficiency and renewable technologies, but provide an indication of the range of benefits provided. EERE will be implementing additional portions of the NRC Framework as these elements are developed.

Table ES.1: EERE FY 2004 Benefits Metrics

Primary Outcome	
Energy displaced	• Reductions in nonrenewable energy consumption
Resulting Benefits	
Economic	• Reductions in consumer energy expenditures
Environmental	• Reductions in carbon dioxide emissions
Security	• Reductions in oil consumption • Reductions in natural gas consumption • Increases in renewable energy-generating capacity

Table ES.2 shows the estimated energy displaced and resulting benefits to the Nation of realizing the EERE program goals associated with the FY 2004 budget request. These impacts are the benefits expected in the reported year—that is, the benefits are annual, not cumulative. Between 2005 and 2020, under a business-as-usual energy future, realization of these goals would:

- Reduce the expected increase in U.S. energy demand by 41%. (**Figure ES.1**)
- Reduce the expected increase in U.S. consumer energy expenditures by 49%. (**Figure ES.2**)

[1] *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, National Research Council (2001). The NRC is the principal operating agency of the National Academy of Sciences (NAS) and the National Academy of Engineering (NAE), providing services to the government, the public, and the science and engineering communities.

- Reduce the expected increase in annual U.S. carbon dioxide emissions by 39%. (**Figure ES.3**)
- Reduce the expected increase in U.S. oil consumption, most of which is expected to derive from outside the United States, by 31%. (**Figure ES.4**)
- Reduce the expected increase in U.S. natural gas consumption, much of which is expected to originate outside the United States, by 45%. (**Figure ES.5**)
- Increase the expected additions to U.S. renewable electric-generating capacity by 553% (**Figure ES.6**) and renewable electric generation by 517%. (**Figure ES.7**)

Table ES.2. Summary of EERE Integrated Portfolio Benefits for FY 2004 Budget Request

EERE Benefits (Annual)	2005	2010	2020
Energy Displaced (quads)	0.6	2.3	8.7
Economic Benefits			
• Energy-expenditure savings (billion 2000 dollars)	8.5	31.2	101.8
Environment			
• Carbon dioxide emission reductions (mmtce equivalent)	10.6	38.9	151.0
Security			
• Oil savings (quadrillion Btu)	0.2	0.7	3.3
• Natural gas savings (quadrillion Btu)	0.4	1.2	3.8
• Renewable electric-generating capacity (gigawatts)	1.5	7.2	39.4

These overall EERE benefits are measured from a Baseline Case, which accounts for the energy efficiency and renewable energy improvements that would be expected to occur even in the absence of EERE programs. The Baseline Case also includes improvements resulting from EERE program efforts in the past. As such, the reported benefits reflect only the net annual improvement from 2005 to 2020 of program activities included in EERE's FY 2004 Budget Request (including subsequent-year funding) and do not include the benefits from past work. Benefits estimates assume the funding will remain constant in inflation-adjusted dollars over the analysis period (or until the completion of the activity) and that the programs will achieve their technology goals and market targets by following multiple technology paths in parallel or sequentially until a successful avenue is found. Because funding continues over time, these technology and market improvements tend to be larger over time (e.g., more can be accomplished with a 10-year effort than a one-year effort).

EERE annually develops these benefits projections pursuant to the Government Performance and Results Act (GPRA) of 1993. The analysis summarized in this report is based on the technological and deployment progress expected by EERE programs, and generally assumes that programs continue to receive their requested funding levels through the completion of each activity. As such, the analysis addresses the performance-budget integration goal of the President's Management Agenda (PMA). This analysis also addresses the benefits criterion in the R&D Investment Criteria, developed by the Office of Management and Budget (OMB) as part of the PMA.

In order to help improve the consistency of estimates across EERE programs, EERE specifies a common methodology and set of assumptions to be used in developing benefits estimates.

The FY 2004 benefits estimates were developed following the guidance in place before the EERE reorganization occurred.[2] Baseline Case assumptions are updated annually to reflect new energy forecasts developed by the Energy Information Administration (EIA) (see **Appendix A**).

EERE uses a three-step process to estimate benefits across its portfolio:

(1) Establishment of the Baseline Case
(2) Determination of program and market inputs
(3) Assessment of program and portfolio benefits.

In Step 1, EERE uses an energy-economy model (NEMS-GPRA04), both to develop the Baseline Case and to estimate the impacts of EERE programs. This model is a modified version of the National Energy Modeling System (NEMS), the principal energy model used by the EIA. EERE modifies EIA's *Annual Energy Outlook 2002* Reference Case (AEO2002) forecast to remove any identifiable effects of EERE programs already included in the forecast. The Baseline Case, therefore, provides a consistent representation of business-as-usual future energy markets without the benefits of EERE programs, and ensures consistent assumptions about future energy prices, conversion factors, economic growth, and other external factors, which might affect the analysis results. A summary of the Baseline Case results is included in **Appendix A.**

In Step 2, once the Baseline Case is established, the EERE program's technology goals (or outputs) are assessed with regard to their likely market impacts. Although many of the program outputs can be characterized by improvements in the costs and performances of the technologies, some of the programs (particularly deployment assistance programs that include activities such as information dissemination, market assessments, and codes and standards) characterize their outputs as market-penetration levels. Because the success or failure of energy technologies can depend heavily on the external-to-DOE market and policy conditions found in each energy market, such conditions must often be taken into account on a case-by-case basis in estimating individual program benefits. **Appendices B through E** describe the market-specific analyses undertaken in this step.

In Step 3, the program- and market-specific information from Step 2 is incorporated into NEMS-GPRA04, which enables accounting for market feedbacks and interactions that can change the ultimate level of energy savings associated with realizing each program's goals. Where program activities cannot be directly modeled in NEMS-GPRA04, initial energy impacts are estimated "off-line" (e.g., without the use of a full, program-wide model). For the FY 2004 benefits analysis, EERE undertook a new approach of adjusting these off-line estimates to account for areas of overlapping program impacts. This (usually) downward revision was made based on judgment of the Integrated Modeling Team of analysts. The resulting benefits estimates of these individual program analyses are listed by program—along with FY 2004 program budgets, in **Table ES.3** below.

[2] Prior to the reorganization, estimates of benefits were made based on guidances developed by EERE's then Office of Planning, Budget, and Outreach. The FY 2004 analysis was begun using the pre-existing guidance for FY 2003 (see http://www.eere.energy.gov/office_eere/ba/gpra_estimates_fy03.html).

NEMS-GPRA04 is also run with all programs simultaneously represented in order to derive estimates of the benefits of the EERE portfolio overall. This portfolio analysis accounts for interactions among EERE's programs and tends to report slightly reduced benefits compared to the sum of the individual programs.[3] These fully integrated results are listed in **Table ES.2,** above, and displayed in the graphs in this **Executive Summary**. Specific details of the representation of the program outputs in NEMS-GPRA04 and the underlying program analysis and documentation are provided in **Chapter 3** of this report.

The budget-planning year for the FY 2004 budget request was a year of transition within EERE. A major reorganization resulted in the consolidation and realignment of 31 programs (analyzed as 46 "GPRA units") across five sectors to just 11 programs (analyzed as 12 "GPRA units" for better correspondence with the budget). The FY 2004 benefits analysis began under the old organization, but concluded with the new organization. As a result, the documentation for Step 2—individual program and market analysis—does not reflect the new program structure nor the more-integrated approach to benefits estimates made possible by the reorganization. Nonetheless, it provides the reader with a sense of the ways in which the inputs to the NEMS-GPRA04 Benefits Estimates described here were calculated.

EERE is pursuing a number of improvements to its benefits analysis. Important changes planned for analysis of the benefits of the FY 2005 budget request include:

- Extension of the benefits projection time frame to 2050 to better capture the longer-term benefits of programs such as the Solar Energy Technologies Program and the Hydrogen, Fuel Cells, and Infrastructure Technologies Program.
- Greater streamlining and consistency in the development of program-level benefits estimates.

In addition, EERE is developing methods for linking estimates of benefits from both past and future program efforts into the overarching NRC benefits framework noted above—as well as developing methods for estimating the option value of preparing the Nation for possible future energy needs beyond business-as-usual. Finally, EERE is developing a more systematic way of representing program and technology risk. Although not part of this benefits analysis *per se*, information on risk is recognized as an important component in the application of benefits information to portfolio management.

[3] In previous years, the difference between the sum of individual program results and the portfolio results were much larger; the small difference in this year's analysis is due in large part to the adjustments made to the off-line estimates in Step 2, described above, as well as the use of NEMS-GPRA04 for program-level results.

Table ES.3. U.S. Department of Energy Office of Energy Efficiency and Renewable Energy: FY 2004 Funding Summary and Selected 2020 Benefits by Program[4]

	FY 2004 Request ($ thousands)	Energy Displaced (quads)	Energy Expenditure Savings (billions 2000$)	Carbon Dioxide Emissions Reductions (million MTce)	Oil-Use Reductions (quads)
Hydrogen, Fuel Cells, and Infrastructure Technologies	165,482	0.2	3.9	4.6	0.2
FreedomCAR and Vehicle Technologies	157,623	1.6	25.5	29.8	1.5
Weatherization and Intergovernmental	369,460	1.4	14.7	26.3	0.6
Solar Energy Technologies	79,693	0.1	1.4	2.4	0.0
Wind and Hydropower	49,089	1.2	5.4	20.9	0.1
Geothermal Technologies	25,500	0.4	1.8	7.5	0.0
Distributed Energy and Electric Reliability	128,650	0.5	9.0	8.5	0.0
Building Technologies	56,563	1.3	16.3	22.7	0.1
Industrial Technologies	64,429	2.1	20.2	36.3	0.5
Biomass	78,558	0.4	1.9	3.6	0.3
Federal Energy Management	22,262	0.1	0.8	1.3	0.0
National Climate Change Technology Initiative	24,500	N/A	N/A	N/A	N/A
Facilities and Infrastructure	4,950	N/A	N/A	N/A	N/A
Program Direction	93,241	N/A	N/A	N/A	N/A
Sum of programs *	**1,320,000**	**9.3**	**100.9**	**163.9**	**3.4**

* The sum of program benefits differs from the EERE portfolio values in Table ES.2, because interactions among programs are not accounted for in the individual estimates. Sums may not total due to rounding.

[4] Budget request from *FY 2004 Budget-in-Brief*, U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/office_eere/pdfs/fy04_budget_in_brief.pdf.

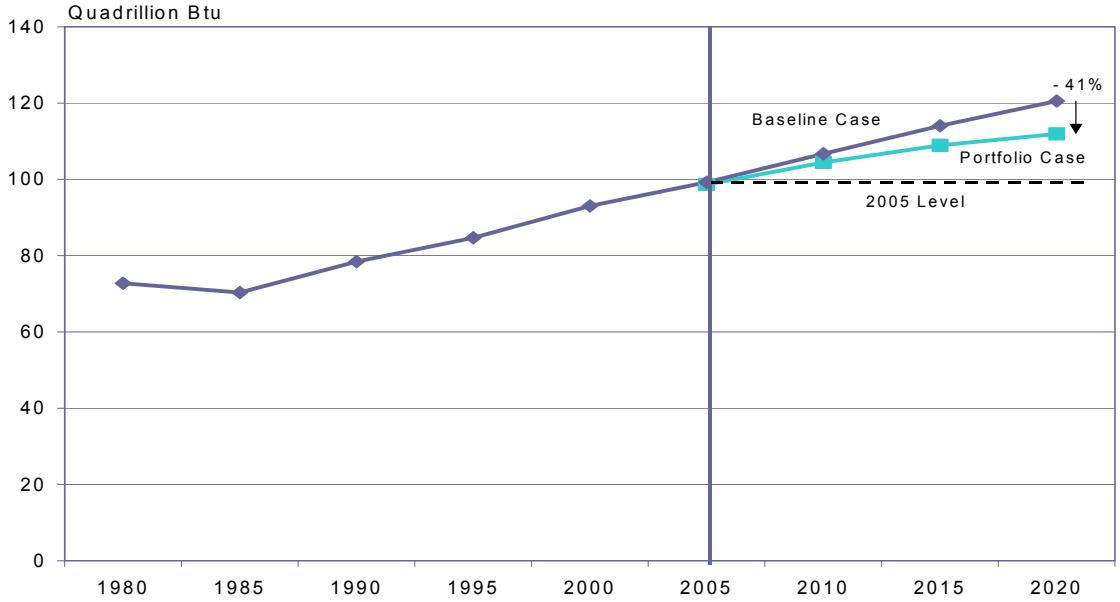

Figure ES.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for year 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

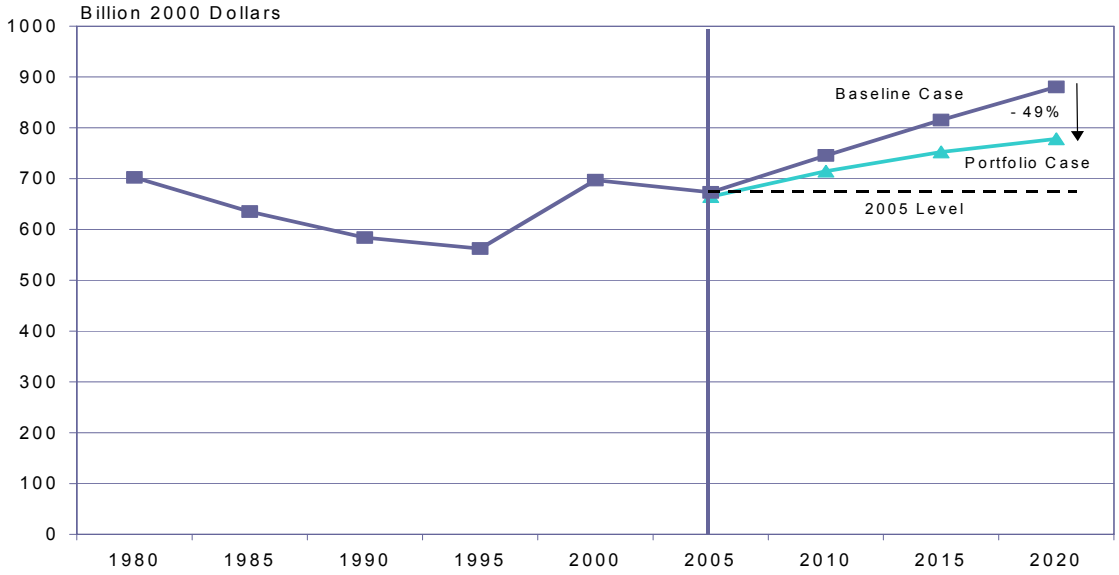

Figure ES.2. U.S. Total Energy Expenditures, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Sources: 1980-1995: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 3.4 and Table E1, Web site http://www.eia.doe.gov/emeu/aer/contents.html; 2000: Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002), Supplemental Table 20.

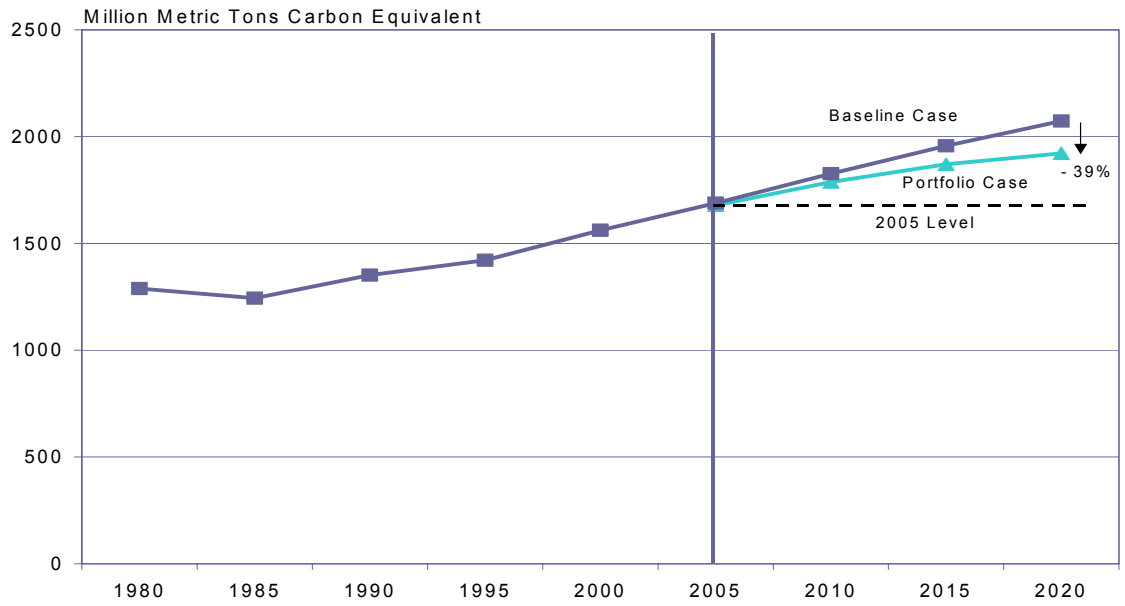

Figure ES.3. U.S. Carbon Dioxide Emissions, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 12.2, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

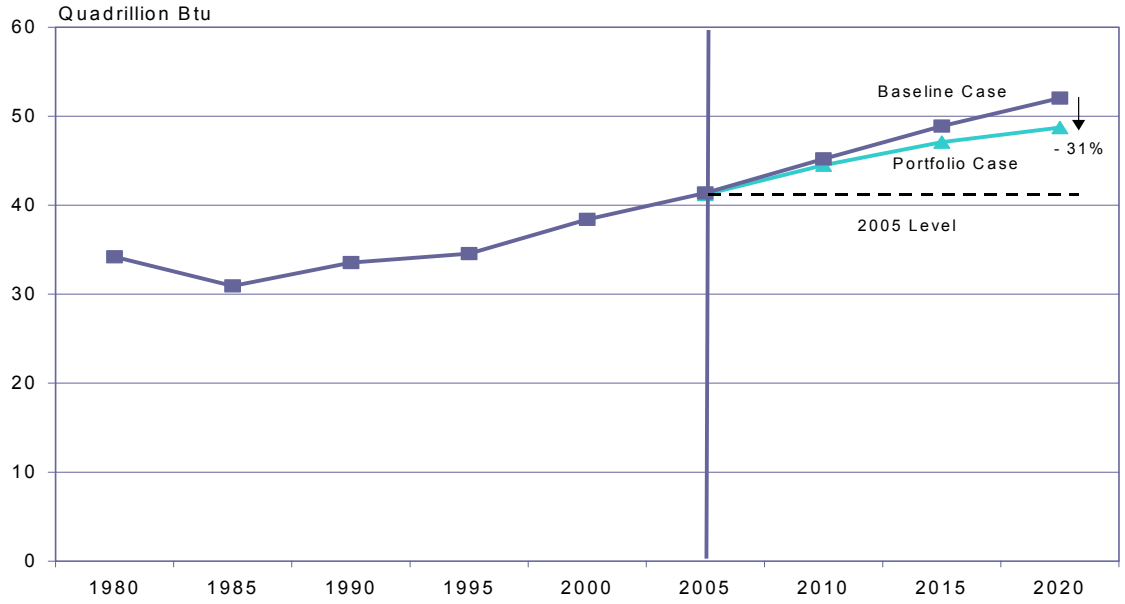

Figure ES.4. U.S. Oil Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

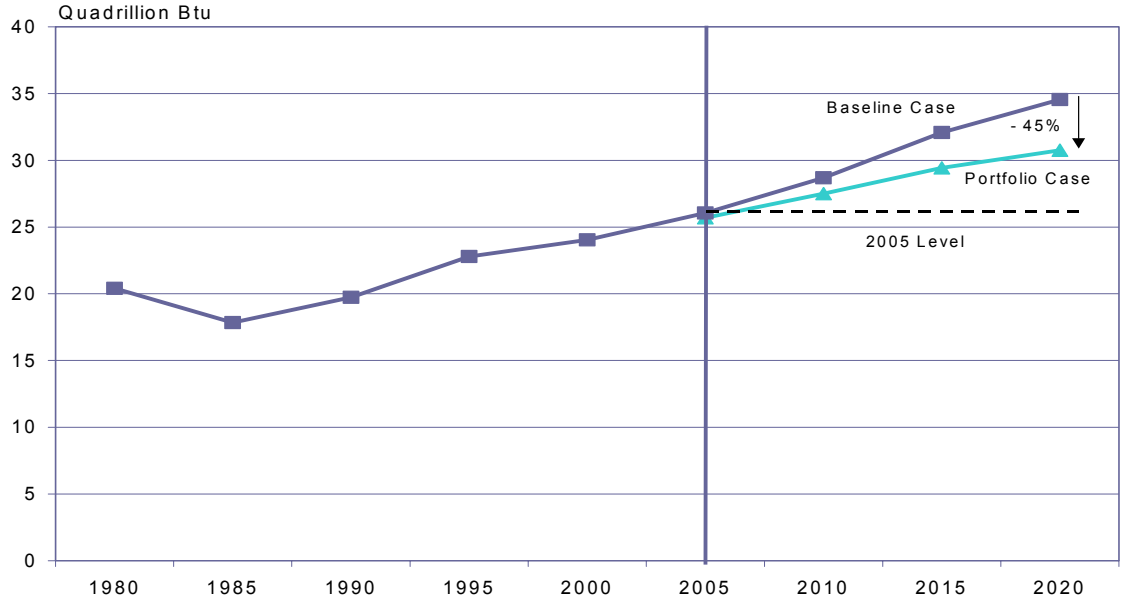

Figure ES.5. U.S. Natural Gas Consumption, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

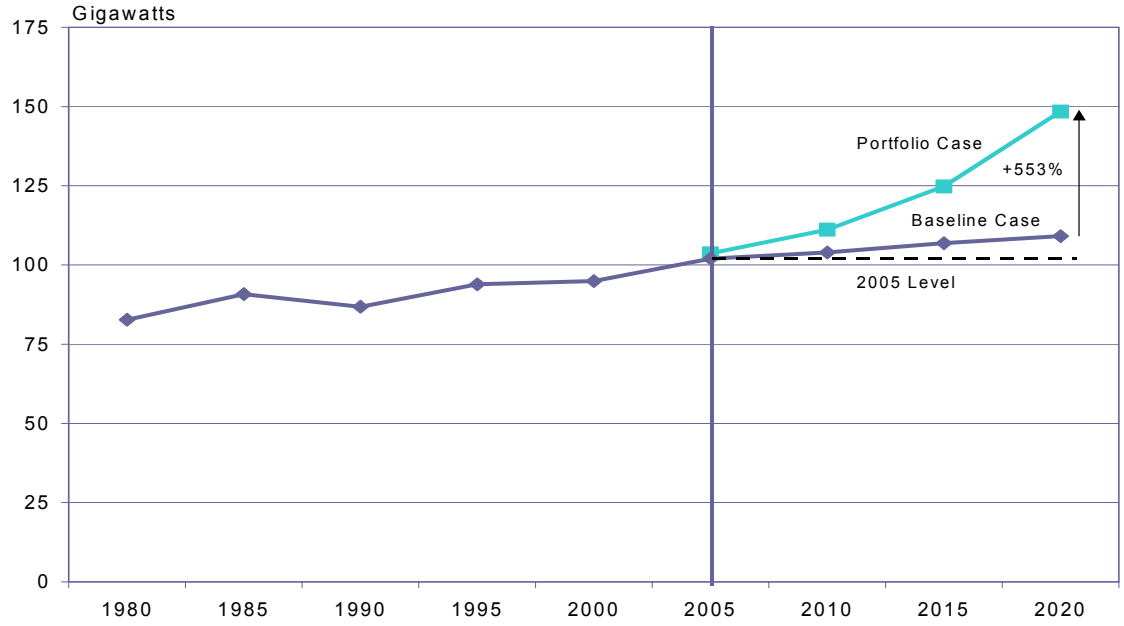

Figure ES.6. U.S. Renewable Electricity Capacity, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 8.7a, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

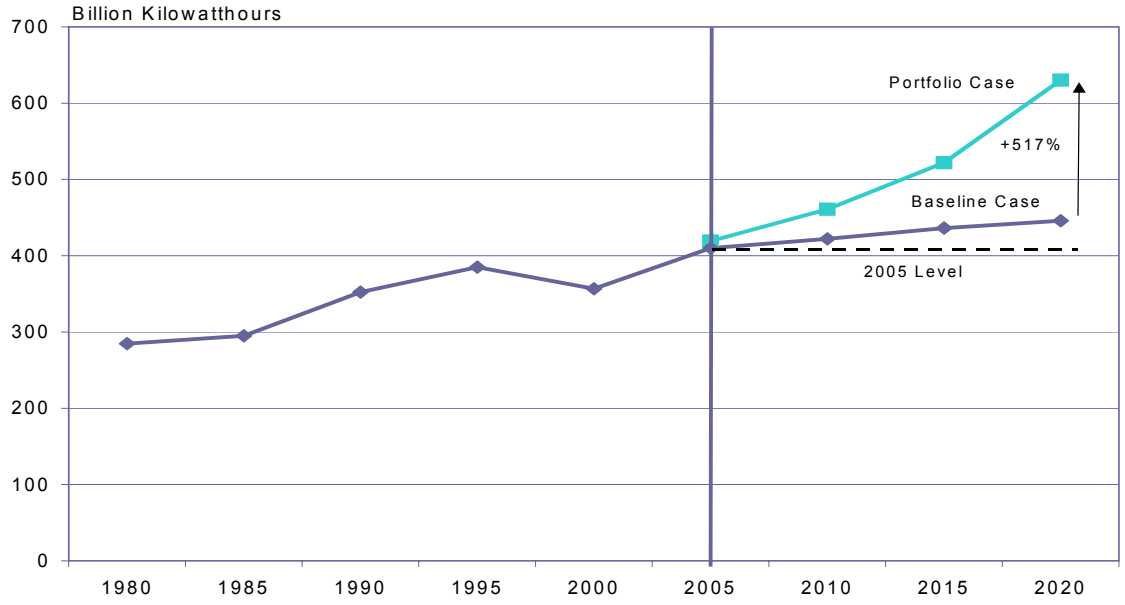

Figure ES.7. U.S. Renewable Electricity Generation, 1980-2000, and Projections to 2020: Baseline and Portfolio Cases

Note: The percentage change in the chart shown for 2020 is the difference between the Baseline Case and the Portfolio Case, compared to the difference between the values of the Baseline Case in 2020 versus 2005.
Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001), Table 8.2a, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

CHAPTER 1

INTRODUCTION

The Office of Energy Efficiency and Renewable Energy (EERE) develops—and encourages consumers and business to adopt—technologies that improve energy efficiency and increase the use of renewable energy. This report describes analysis undertaken by EERE to better understand the extent to which the technologies and market improvements funded by its FY 2004 Budget Request[1] will make energy more affordable, cleaner, and more reliable.

The Government Performance and Results Act (GPRA) of 1993 requires Federal Government agencies to prepare strategic plans, annual performance plans, and annual performance reports. This EERE benefits analysis supports these GPRA requirements by developing an assessment of the benefits that may accrue to the Nation if the performance goals of EERE's programs are realized. The consumer energy-cost savings,[2] carbon emission savings, and reduced reliance on fossil fuels estimated here result from the increased use of energy-efficient technologies and increased production of renewable energy resources, which are supported by the technology advances and market adoption activities pursued by EERE programs.

EERE initiated its benefits analysis in 1994. Through the 1990s, EERE program offices continued to refine their benefits-analysis methodologies and assumptions, and an annual external review of the methodologies and assumptions employed was initiated in 1997 and continued through 2001 when EE was reorganized. Although the benefits analysis has changed since it was initiated 10 years ago, the energy saved or displaced continues to be the key measure of the EERE program impact.

With its reorganization in 2002, EERE centralized the benefits-analysis effort within the Office of Planning, Budget Formulation, and Analysis (PBFA) and integrated it into the broader planning and analytical needs of EERE. While technology information (such as cost and performance) is still provided by the EERE programs, market analysis is now conducted by PBFA.

The analysis summarized in this report is based on the technological and deployment impacts of the EERE program activities, with the following key assumptions:

- Programs will be funded at the levels requested in DOE's fiscal year (FY) 2004 Budget Request;
- Funding levels will remain constant in inflation-adjusted dollars or rise to accommodate key initiatives in particular cases, as indicated;

[1] See http://www.eere.energy.gov/office_eere/budget.html.

[2] These consumer cost savings are the gross savings from avoiding purchased energy. They are not net of the investments that would have to be undertaken to achieve these savings. The NEMS model does not currently address net costs, and these are considered separately.

- Programs will achieve their technology and market targets and goals based on the assumption that one of the many technical paths pursued will succeed. It is important to note that this assumption of technical success, although uncertain, is generally not dependent on a single technical pathway and instead encompasses a number of alternative approaches, of which many may fall short without jeopardizing realization of the final goal. For most programs, the basic technical capability for achieving the overall goal is already demonstrated. For example, the efficiency of thin-film photovoltaic cells needed to achieve the overall PV program goal already has been demonstrated in the laboratory, and no additional breakthroughs are needed. Further, there are several completely different PV materials and manufacturing processes by which the goal could be realized. For some technologies, significant technical advances are still needed.

The analysis is budget-based. As such, it addresses the performance-budget integration goal of the President's Management Agenda (PMA). It also addresses the benefits criterion in the R&D Investment Criteria developed by the Office of Management and Budget (OMB) as part of the PMA.

Role of Benefits Analysis in Performance Management

EERE employs a widely used logic model as the foundation for managing its portfolio of efficiency and renewable investments[3] and for ensuring that these investments provide energy benefits to the Nation. In its simplest form, this logic model identifies budget and other *inputs* to a program, *activities* conducted by the program, and the resulting *outputs* and *outcomes* of those activities (**Figure 1.1**). The logic model provides an integrated approach that explicitly links requested budget levels to performance goals and estimated benefits—and helps ensure that estimated benefits reflect the funding levels requested. The elements of the logic model are specified in GPRA and are included in the annual budget request.

Multiyear Program Plans (MYPPs),[4] developed by each of EERE's 11 programs, address the *inputs* required, the *activities* that will be undertaken with their requested budget, the performance *milestones* they expect to achieve as they pursue these activities, and the resulting products or *outputs* of this effort.[5] Inputs may include cost-shared or leveraged funds as well as EERE program dollars—and may also include advances by others on which the program builds. Performance milestones capture intermediate points of discernable progress toward outputs and are used by program managers, DOE, OMB, and others to track program progress toward their

[3] The logic model is a fundamental program planning and evaluation tool. For more information on logic models, see: Wholey, J. S. (1987). *Evaluability assessment: developing program theory. Using Program Theory in Evaluation*. L. Bickman. San Francisco, CA, Jossey-Bass. 33. Jordan, G. B. and J. Mortensen (1997). "Measuring the performance of research and technology programs: a balanced scorecard approach." *Journal of Technology Transfer* 22(2). McLaughlin, J. A. and J. B. Jordan (1999). "Logic models: a tool for telling your program's performance story." *Evaluation and Program Planning* 22(1): 65-72.

[4] These program plans are being formalized as part of the EERE reorganization. Final plans will be available during 2004. For this transitional year, benefit analysts worked with any updated program goals available and utilized existing goal statements where necessary.

[5] See the Government Performance Results Act (GPRA) of 1993 at http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html and http://www.whitehouse.gov/omb/circulars/a11/02toc.html

outputs. Outputs, often referred to as "program goals" or "program performance goals,"[6] are the resulting products or achievements of an overall area of activity. EERE's R&D programs typically specify their outputs in terms of technology advances (e.g., reduced costs, improved efficiency), while deployment programs develop outputs related to their immediate market impacts (e.g., number of homes weatherized). Outputs[7] evolve over time as the program pursues increasing levels of technology performance or market penetration.

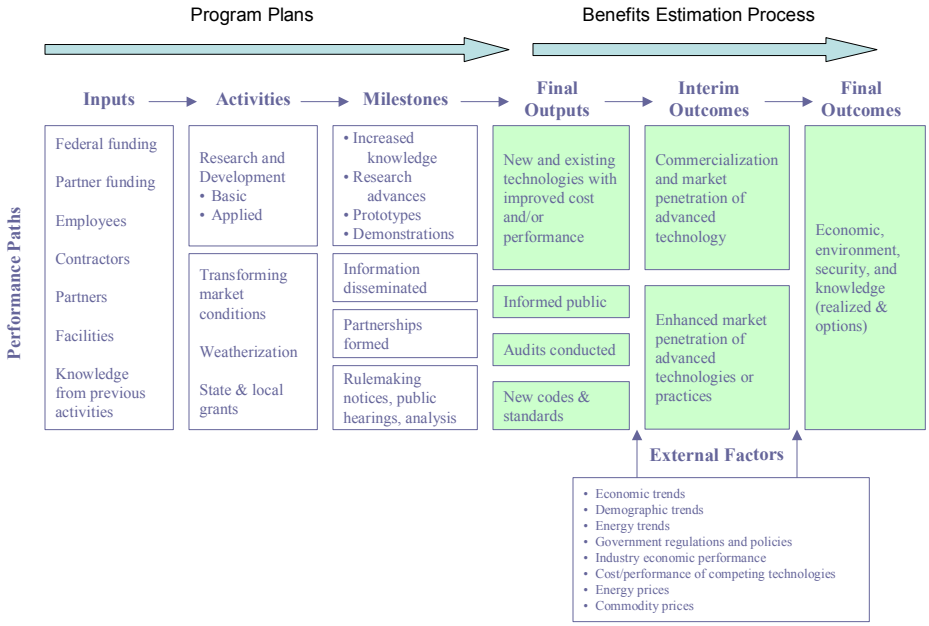

Figure 1.1. Generalized EERE Logic Model

This benefits analysis links these program outputs to their market impacts or outcomes. EERE's programs have discernable effects on energy markets, both by reducing the level of energy demand (through efficiency improvements) and by changing the mix of our energy supplies (through increased renewable and distributed energy production). EERE incorporates these two effects in its primary *outcome*—the displacement of conventional energy demand.

These changes in energy use provide the basis for the economic, environmental, and security benefits estimated here. The extent to which a new technology or a deployment effort changes energy markets will depend on a variety of external factors. The future demand for energy, its price, the development of competing technologies, and other market features (such as consumer preferences) all will contribute to the marketability and total sales of a new technology.

[6] Some programs derive their outputs through technology-cost simulation models to develop the specific requirements to meet overall program cost and performance goals. Specific details of the representation of the program outputs in NEMS-GPRA04 and the underlying program analysis and documentation are found in Chapter 4 of this report and Appendices B through E.
[7] The level of risk for the programs is assessed qualitatively as part of the Office of Management and Budget (OMB) R&D Investment Criteria. EERE is developing a standard approach to assessing technology and program risk.

Benefits Framework

The EERE Benefits Framework addresses the last three columns of the logic model: the link between program outputs with resulting outcomes and benefits. The benefits analysis is based on the specific program goals or outputs specified by EERE programs in their program plans and the EERE budget request, and on estimated future energy market conditions (external factors). EERE estimates its primary outcome—displaced conventional energy consumption—by comparing future energy consumption with and without the contributions of its program outputs. The market impacts of each of the 11 programs are assessed separately and then combined to assess the benefits of EERE's overall portfolio.

EERE, along with the Office of Fossil Energy (FE), is in the process of adopting a framework initially developed by the National Research Council (NRC) to assess the benefits associated with past EERE research efforts (see **Box 1.1, National Research Council Review**). EERE's annual estimates of prospective benefits have been incorporated into an integrated framework addressing the benefits of both existing and future program activities. The framework is represented in a matrix, in which the rows distinguish among four types of benefits and the columns represent different elements of time and uncertainty.

This report addresses the three shaded cells of the matrix, reflecting benefits under a business-as-usual energy future. EERE and FE currently are developing methods for assessing the value to the country of developing technologies that prepare the Nation for unexpected energy needs. These results will be in the "option" column in future reports.[8] Similarly, EERE is in the process of extending the NRC analysis of realized benefits to include its full portfolio (**Figure 1.2**).

	Realized Benefits and Costs	Expected Prospective Benefits and Costs	Options Benefits and Costs
Economic Benefits and Costs		X	
Environmental Benefits and Costs		X	
Security Benefits and Costs		X	
Knowledge Benefits and Costs			

Figure 1.2. FY 2004 Benefits Metrics Reported

Completing the cells of this matrix in ways that provide comparable results across programs (and DOE offices) poses a number of analytical challenges, especially in light of the varied portfolio that EERE maintains:

- **Standard baseline(s) and methodology.** EERE uses the Energy Information Administration's (EIA) reference case as a consistent starting point for analysis of all of its programs. A standard methodology is used to assess the incremental improvements to energy efficiency and renewable energy production, resultant from realization of EERE

[8] For its retrospective study, the NRC defined an option as a technology that is fully developed—but for which existing market or policy conditions are not favorable for commercialization. Because current technology choices are known, noncommercial (but developed technologies) are options, by default. A more general definition for prospective analysis—expressed in the Real Options literature—defines a real option as an asset, such as a technological innovation that creates future choices (i.e., options) and establishes an analytic decision-making framework on how to enhance asset value at future points in time. See Dixit, Avinash K., and Robert S. Pindyck, *Investment under Uncertainty*, Princeton University Press, Princeton, New Jersey (1994).

program goals. This methodology addresses approaches and assumptions that are applicable to all of EERE's program activities and markets.

- **Varied markets.** Program activities target all end-use markets (buildings, industry, transportation, and government) and energy supply markets (use of renewable energy as new sources of liquid and gaseous fuels, and electricity). Because these markets vary enormously in structure, regulation, and consumer preferences, a fairly detailed, market-specific analysis often is needed to gain sufficient understanding of the size and potential receptivity of each market to EERE's activities. EERE strives to incorporate these unique market features that are likely to have a significant impact on the resulting benefits.

- **Varied time frames.** The analytical time frame extends from a few years to the decades that are required for the development of new energy sources, infrastructure, market penetration, and product life cycle. This expansive time frame requires a baseline and analytical tools that can address energy markets in the short, mid-, and long term. This report addresses short- (5–10 years) and mid-term (10–20 years) time frames. EERE is developing tools to address the long term (20–50 years) for the FY 2005 budget cycle.

- **Numerous market feedbacks.** EERE technology and deployment efforts can have large enough effects on their respective energy markets that they generate supply or price feedbacks. EERE's products also can interact with each other across their respective energy markets. For example, efficiency improvements in end-use markets can be large enough to forestall the development of new electricity-generating plants, reducing the potential growth of wind and other renewable electricity sources. Past EERE experience indicates that failure to reflect market responses tends to overestimate benefit levels. EERE utilizes an integrated energy-economic model to produce final benefit estimates that consider these feedbacks and interactions at the program and portfolio levels.

EERE's 2002 Reorganization

EERE reorganized in June 2002. The previous organization, consisting of five sectors (buildings, federal, industry, power, and transportation) and 31 programs was replaced by a set of 11 programs. This reorganization facilitated use of the logic model, with clear program responsibilities for linking inputs to outputs. A new analysis group—Planning, Budget Formulation, and Analysis (PBFA)—assumed responsibility for assessment of outcomes and benefits related to these program outputs.

Under the prior organization, benefit analyses were undertaken by each of the five sectors for the programs within their sector, with guidance provided by EERE management. These analyses provided program-level estimates of benefits, but did not account for feedbacks from other markets—or, in some cases, even within target markets. The annual guidance provided a consistent basis for estimating benefits across programs, but the disaggregated nature of the analysis often made it difficult to implement this guidance in a consistent way. The energy savings from these individual program estimates were then assessed, using an energy-economic model to estimate the savings across EERE's entire portfolio.

The new organization brings together a team of analysts, which includes experts in both individual energy markets and energy-economic modeling. This new team enables EERE to take market feedbacks into account at the program level, as well as at the portfolio level. It also enables analysts to improve coordination in implementing EERE's benefits methodology.

The FY 2004 benefits analysis was initiated under the old organization. As a result, the program-level analyses were undertaken based on the prior sector structure. As in past years, each sector report (**Appendices B through E**) includes program-level energy savings estimates, which do not include feedback effects. With the creation of the integrated analysis team midway through this analysis effort, it was possible to produce a final set of 11 program benefit estimates that account for market feedbacks. It is these final integrated estimates that are included in this report and that appear in the EERE FY 2004 Budget Request.

Analysis Team

This report summarizes program benefits analysis undertaken by experts in energy technology programs, energy markets, and energy-economic modeling. The primary team members and their areas of responsibility are listed below.

Management and Overall Responsibility

- EERE
  - Integrated: MaryBeth Zimmerman, Susan Holte, Phil Tseng
  - Buildings: Jerry Dion
  - Industry: Ken Friedman, Peggy Podolak
  - Transport: Phil Patterson
  - Power: Tina Kaarsberg, Susan Holte
  - Bioenergy: Tien Nguyen
- Contractors
  - Project Managers: Bill Babiuch, Doug Norland (NREL)
  - Guidance: Patrick Quinlan (NREL), John Mortensen (Independent Consultant), Jim Wolf (Independent Consultant)
  - Energy-Economic Integration: Frances Wood, John Holte, Aliza Seelig (OnLocation, Inc.); Chip Friley, John Lee (BNL)

R&D and Deployment Programs

- Biomass: Jerry Hadder (ORNL); Michael Wang (ANL); Roger LeGassie, Steve Zukor (TMS); David Andress (D. Andress & Associates); Margaret Singh (ANL); David Andress, Tracy Carole (Energetics); Larry Goldstein (NREL); Tom Schweizer (PERI)
- Buildings: Dave Anderson, David Belzer, Katie Cort, Jim Dirks, Donna Hostick, Sean McDonald (PNNL)
- Distributed Energy and Electric Reliability (DEER): Larry Goldstein (NREL), Tom Schweizer (PERI)
- Federal Energy Management Program (FEMP): Daryl Brown, Andrew Nicholls (PNNL)

- FreedomCAR and Vehicle Technologies: Margaret Singh (ANL), Elyse Steiner (NREL), Jim Moore (TA Engineering, Inc.)
- Hydrogen and Fuel Cells: Margaret Singh, Steven Plotkin (ANL); Elyse Steiner (NREL)
- Geothermal: Larry Goldstein (NREL); Tom Schweizer, Dan Entingh (PERI)
- Green Power: Jim McVeigh (PERI)
- Industry: Jim Reed (Independent Consultant); Joan Pellegrino, Nancy Margolis, Shawna Mcqueen, Diane McBea (Energetics); Ken Greene, Bill Choate, Roy Tiley (BCS); John Mortensen (Independent Consultant); Douglas Norland (NREL); Peter Angelini (ORNL); Elmer Fleischman (INEL)
- Inventions and Innovations: Nancy Moore (PNNL)
- Renewables (all): Chris Marnay, Kristina Hamachi LaCommare (LBNL)
- Solar: Larry Goldstein (NREL), Tom Schweizer (PERI)
- Wind and Hydropower: Larry Goldstein (NREL), Tom Schweizer (PERI)
- Weatherization and Intergovernmental Programs (WIP): David Anderson, David Belzer, Katie Cort, Jim Dirks, Donna Hostick, Duane Deonigi, Nancy Moore (PNNL)

In all cases, these lead analysts drew on the studies and expertise of many others. Much of this supporting work can be found in the references provided here and in the appendices.

Report Organization

This report is organized into three additional chapters. **Chapter 2** describes the process and methodology employed by EERE to estimate program and portfolio economic, environmental, and security benefits from its RD&D programs. **Chapter 3** presents the overall results of the savings estimates from the individual programs and from a total EERE portfolio perspective. **Chapter 4** describes, in detail, the results of each program area.

Five appendices are included. **Appendix A** provides the Baseline and Portfolio Cases. **Appendices B through E**, respectively, provide sector-analysis team inputs for buildings, industry, renewables, and vehicles.

Box 1.1—National Research Council Review

Energy Research at DOE: Was It Worth It?

In 1999, at the request of the U.S. Congress, the National Research Council (NRC) of the National Academy of Sciences began a retrospective study of the benefits of EERE energy efficiency RD&D programs, examining activities from 1978 to 2000. The activities examined accounted for about one-fifth of the cumulative EERE funding for energy efficiency projects, excluding renewable technology programs. Using a conservative methodology to evaluate about $1.6 billion of the EERE energy efficiency programs, the NRC found a net realized economic benefit of approximately $30 billion, or a return of about $20 for each $1 of EERE investment in the programs considered.* Also included in the study were the R&D programs of DOE's Office of Fossil Energy.

The methodological framework developed by the NRC was designed to reflect the public policy purpose of the R&D and the state of commercialization of the R&D activity. A matrix was developed to represent these features, as shown in the table below. The rows of the matrix represent the net benefits to be achieved by the R&D (accounting for any extra costs as well as benefits associated with the new technology). After reviewing energy policy documents, the committee concluded that the benefits of energy R&D can be grouped into three primary categories: economic benefits, environmental benefits, and security benefits (including reliability).

The columns of the matrix represent the state of the R&D activity and related technologies at the time of the evaluation. Realized benefits are those achieved by technologies that have been successfully developed or are in final development and demonstration, for which current economic and policy conditions are favorable for deployment in the marketplace. Options benefits are for technologies that are under development or are technologically successful, for which economic or policy conditions are not yet favorable to their deployment but could become favorable under reasonable future scenarios. Knowledge benefits are for those technologies for which R&D is not yet completed, for technologies that would not be commercialized, and for technologies for which development was unsuccessful but nevertheless yielded knowledge that is potentially applicable elsewhere. The NRC study did not evaluate knowledge benefits for successful technologies.

	Realized Benefits and Costs	Options Benefits and Costs	Knowledge Benefits and Costs
Economic Benefits and Costs			
Environmental Benefits and Costs			
Security Benefits and Costs			

DOE's offices of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, and Science cosponsored DOE's "Estimating the Benefits of Government-Sponsored Energy R&D"** (March 2002) to explore ways of extending this framework to include the prospective benefits of program activities. As a result of the conference, the matrix was revised by placing knowledge as a benefit and explicitly showing expected prospective benefits and costs in addition to realized benefits and costs.

* The estimated benefits were based on analyses of 17 case studies. The estimated benefits also assumed that without the EERE program, the technology would have been developed and introduced in the market five years later by the private sector. In addition, the NRC stopped counting benefits for technology units entering the market after 2005.
** See www.esd.ornl.gov/benefits_conference.

CHAPTER 2

EERE BENEFITS-ANALYSIS PROCESS

The Office of Energy Efficiency and Renewable Energy's (EERE) benefits-analysis process involves three major steps (**Figure 2.1**). **Step 1** provides a consistent baseline for the analysis, which reflects an energy future without EERE's contributions, along with a standard methodology (guidance) to help ensure consistency in estimates across programs. **Step 2** provides the specific technology and market information, which is necessary to understanding the potential roles of each program in its target markets. In **Step 3**, this program and market information is used to assess the impacts of each EERE program, as well as the overall EERE portfolio, on energy markets in the United States using an integrated energy-economic model.[1]

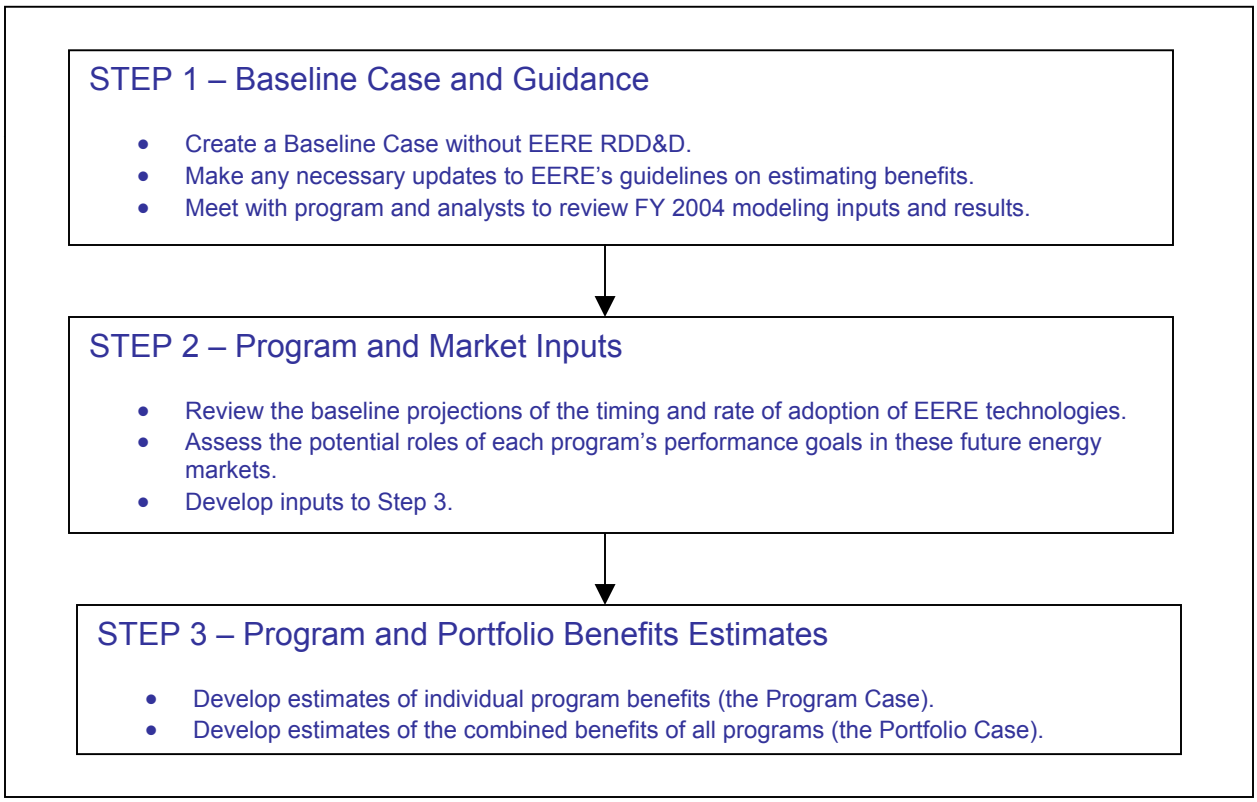

Figure 2.1. EERE Program and Portfolio Benefits-Analysis Process

[1] The FY 2004 benefits assessment was already well underway at the time of EERE's reorganization in June 2002. As a result, the analysis described here and in the appendices is something of a hybrid between the pre-reorganization process and the new process described here.

Step 1: Baseline Case and Guidance

Baseline Case

The EERE Baseline Case is a projection intended to represent the future U.S. energy system without the effect of EERE programs. This Baseline Case is intended to serve four purposes: First, it assures that these initial assumptions are consistent with each other; e.g., that the level of electricity demand expected under the economic growth assumptions could be met at the electricity price assumed. Second, it assures that each program's benefits are estimated based on the same initial forecasts for economic growth, energy prices, and levels of energy demand. Third, it provides a basis for assessing how well renewable and efficiency technologies might be able to compete against future, rather than current, conventional energy technologies (e.g., more efficient central power generation). Finally, it helps ensure that underlying improvements in efficiency and renewable energy are not counted as part of the benefits of the EERE programs.[2]

EERE utilized the most recent Annual Energy Outlook (AEO) Reference Case as the starting point for developing this base case.[3] The Energy Information Administration (EIA) AEO Reference Case provides an independent representation of the likely evolution of energy markets. This forecast reflects expected changes in the demand for energy, technology improvements that might improve the efficiency of energy use, and changes in energy-resource production costs, including renewable energy. Current energy policies, such as state renewable portfolio standards (RPS), which facilitate the development and adoption of these technologies, are included in the Baseline Case. This approach ensures that EERE's benefits estimates do not include expected impacts of such policies.

In establishing its Baseline Case, EERE makes a number of modifications to the EIA Reference Case in order to remove discernable representations of EERE programs and to update policy and market factors where additional information is available. These modifications are made using the same model, the National Energy Modeling System (NEMS), used by EIA in developing the AEO. To distinguish it from EIA's version, the model is referred to as NEMS-GPRA04.

EIA includes some of the impacts of EERE's programs in its Reference Case. These representations are removed from the EERE Baseline Case so that they can be analyzed in the Program Case. Those impacts that are *explicitly* represented in the EIA Reference Case are removed from the EERE Baseline Case. For example, scheduled but not yet completed appliance standards are in the AEO. They are removed for this Baseline Case so that their benefits can be assessed as part of the Building Technologies Program. Beyond the specific program representations, removing the impacts of future program results from the EIA reference case is very difficult. The AEO2002 forecast includes technology improvements in virtually all areas of energy demand and supply; and no clear means of identifying what portion is due to future

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[2] EERE is codeveloping, with the Office of Fossil Energy, scenarios to reflect several potential energy futures, pursuant to a recommendation by the National Research Council to reflect market uncertainties (referred to as "option value") and suggestions made in a follow-up conference on ways to represent market uncertainties in benefits analysis. Scenarios will include differences in policy as well as potential differences in energy markets.

[3] *The Annual Energy Outlook 2002 with Projections to 2020*, December 2001, DOE/EIA-0338 (2002). See http://www.eia.doe.gov/oiaf/archive/aeo02/pdf/0383(2002).pdf.

EERE program efforts is currently available. In the absence of a clear-cut approach to removing program-induced technology improvement from the Baseline Case, no modifications are made to the technology assumptions of the AEO2002. This approach underestimates EERE program benefits.

The EERE Baseline Case also is updated to reflect new policy or market information. The production tax credit (PTC) for wind and closed-loop biomass, for example, is extended to 2003 in the FY 2004 EERE Baseline Case. The extension was not included in the AEO2002 Reference Case, because the PTC extension occurred after the AEO2002 was completed. Market factors are similarly updated. Residential lighting demand, for example, is substantially increased in the EERE Baseline Case, based on a recent lighting-markets report performed for EERE.[4] This change also was adopted by EIA for the AEO2003 but is not reflected in the AEO2002, on which this analysis was based. Similarly, the limit on the share of generation in each region that can be met with intermittent technologies is raised from a limit of 12 percent to 30 percent, based on experience with the introduction of intermittent power in other countries. Building this updated policy and market information into the Baseline Case, as well as the Program Case, helps ensure that the analysis does not ascribe credit for these external developments to EERE program activities.

The adjustments to the AEO2002 Reference Case result in an insignificant difference in energy consumption. For example, in 2020, conventional energy demand in the AEO2002 Reference Case is 121.9 quads. The EERE Baseline Case value is 120.5 quads, a 0.6 quad difference. If graphed in **Figure 2.2**, the AEO2002 Reference Case data for conventional energy demand would virtually overlay EERE's Baseline Case.

Nonrenewable energy demand in the Baseline Case increases by 21 percent from 2005 to 2020. Underlying energy efficiency and renewable energy improvements, however, contribute toward a 23 percent reduction in conventional energy intensity (conventional energy used per dollar of GDP produced), due to private-sector R&D advances and investments, as well as structural changes in the economy during the same period (**Figure 2.2**).[5] Between 2005 and 2020, renewable energy technology improvements result in increases in electric generation (in billions of kWh) of 17.2 for geothermal, 15.3 for biomass, 6.5 for wind, 5.7 for municipal solid waste, 0.6 for photovoltaics, and 0.2 for solar-thermal. More detail from EERE Baseline Case projections is in **Appendix A**. EERE benefit estimates do not include any of these Baseline Case improvements. Rather, the R&D improvements represented in this case provide the "next best technologies" to which additional EERE improvements are compared.

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[4] Navigant Consulting, *U.S. Lighting Market Characterization, Volume I*, September 2002.

[5] Energy-intensity changes result from a mix of structural changes in the economy (e.g., growing service sector) and efficiency improvements. Two recent EERE-sponsored studies provide additional background on understanding the sources of changes to our energy intensity: Ortiz and Sollinger, *Shaping Our Future by Reducing Energy Intensity in the U.S. Economy; Volume 1: Proceedings of the Conference* (2003, Rand Corporation); and Bernstein, Fonkych, Loeb, and Loughran, "State-Level Changes in Energy Intensity and their National Implications," (2003, Rand Corporation).

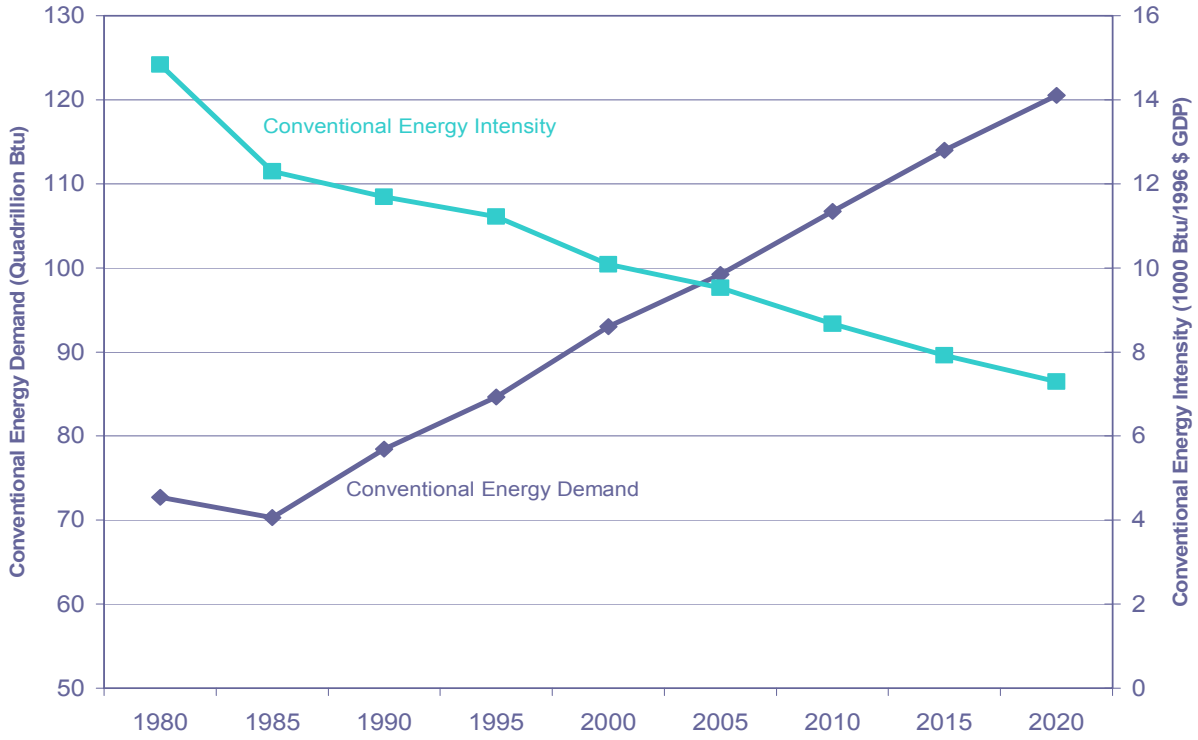

Figure 2.2. U.S. Conventional Energy Demand and Energy Intensity, 1980-2000, and Baseline Projections to 2020

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Tables 1.3, E1 Web site http://www.eia.doe.gov/emeu/aer/contents.html.

Guidance

In order to improve the consistency of estimates across EERE's portfolio, EERE utilizes common methodological approaches, definitions, and conversion factors. Prior to the reorganization, these common elements were provided in the form of an annual "GPRA Data Call"[6] to the five EERE Sectors, which undertook separate analyses based on these common guidelines. With the reorganization, the benefits-analysis team utilizes this methodology directly, including:

Definitions. Common definitions for benefits metrics and related terms are provided.

Converting nominal dollars to real dollars. EERE's benefits analysis is done in constant or real dollars (i.e., without inflation). In cases where future expenditures or costs are provided by the program or other sources in nominal dollars, these are converted to constant dollars based on a forecasted GDP deflator.

[6] The guidance used for FY 2004 benefits estimates followed the guidance for FY 2003 (see http://www.eere.energy.gov/office_eere/ba/gpra_estimates_fy03.html). EERE will continue to maintain standard assumptions and methodologies for estimating program benefits.

Next best technology. The benefits of EERE technologies are assessed compared to the best technologies otherwise available to the market, not simply the technologies available or installed today. The Baseline Case provides the future "next best technologies" against which EERE technologies will compete. In markets where the model does not have explicit technology representation, the "next best technology" is reflected in the Baseline Case rates of technology and market improvements. EERE assumes that its R&D efforts work principally to accelerate the development and introduction of these technologies, while its deployment efforts principally accelerate the market penetration of technologies once they have reached the market.[7] In specific cases, the RD&D efforts also may be directed toward changing the attributes of technologies in the market (e.g., less polluting) or of developing technologies that are not reflected in the Baseline Case within the timeline of analysis. (See **Box 2.1 – Impact of EERE Programs**).

Market characteristics and penetration rates. It takes time for new products to fully saturate their target markets, and these market-penetration rates vary considerably by technology and market. The Baseline Case includes assumptions about technology adoption rates for many markets, primarily through the use of consumer "hurdle rates" or other representations of the trade-off between upfront investment costs and energy savings over time, as well as other attributes in selected cases. Where technologies are not explicitly represented, adoption rates are embedded in efficiency trends. Other market characteristics (such as regional markets, regulatory constraints, or typical start-up time for new product lines) can influence adoption rates and also may be specifically represented in the Baseline Case. For R&D activities, the market characteristics and factors affecting adoption rates are assumed to remain the same for the Program Case and the Baseline Case, unless there is a basis for assuming that the new technology would fundamentally change the way the target markets operate (e.g., accelerate stock turnover or increase consumer acceptance of new technologies). For deployment activities, the program output goals provide a basis for assessing the expected acceleration of market-penetration rates, or other changes in market characteristics, due to the program activities in the Program Case.

Technology performance and cost. For R&D programs, the benefits analysis is based on the performance and cost of the technologies being developed or deployed. For each technology (or class of technologies), key technology characteristics (TCs) include:

- Expected year of technology availability
- Capital costs
- Operations and maintenance (O&M) costs
- Technology product lifetime
- Technology performance and/or energy displaced/unit by fuel type
- Other technology features that might affect market acceptance.

[7] This is a starting assumption. There may be cases in which EERE's efforts principally change the characteristics of the technologies being marketed (e.g., less polluting) rather than, or in addition to, accelerating market introduction and penetration. At times, EERE may be developing technologies that are not expected to be developed by the private sector (i.e., they do not show up in the Baseline Case at all). Finally, some research efforts include built-in deployment components that may result in a combined accelerated introduction and accelerated penetration effect. These variations on the basic approach described above are addressed in the sector-level appendices to this report.

Box 2.1—Impact of EERE Programs

For EERE R&D efforts, the initial assumption is that the impact of the program is to accelerate the commercial introduction of a technology (see **Figure 2.4a**).[1] In some cases, that may be the only effect. In other cases, the EERE R&D effort may develop a technology with features that can affect the ultimate size of the market, or that otherwise would not have been developed by the private sector.* For EERE deployment efforts, the initial assumption is that the impact of the program is to accelerate the rate of adoption of a technology already developed and introduced to the market (see **Figure 2.4b**). In some cases, the EERE deployment effort also may impact the total size of the market, in addition to the rate of adoption. In such cases, the program affects the maximum market share the technology achieves.

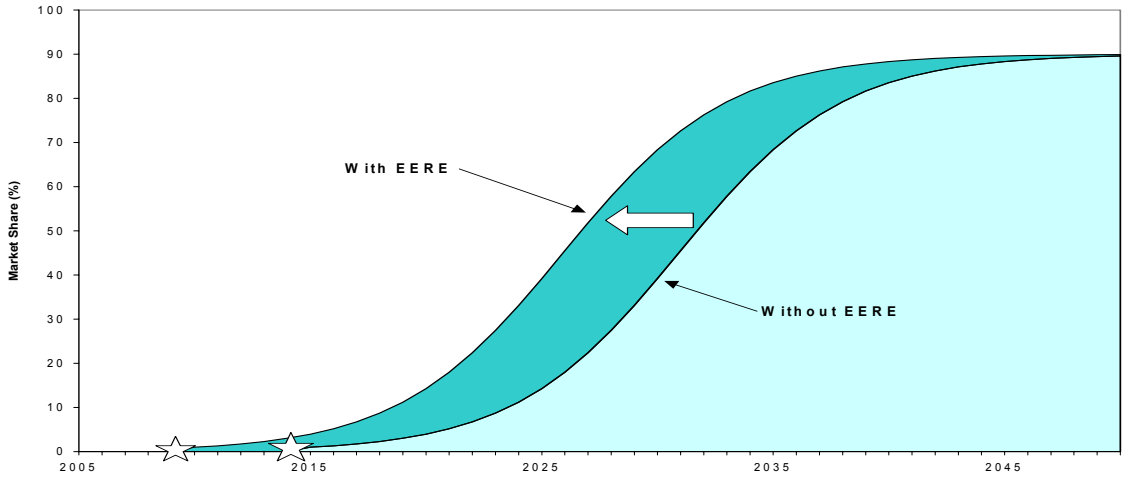

Figure 2.4a. Potential Impacts of EERE R&D Programs on Technology Introduction

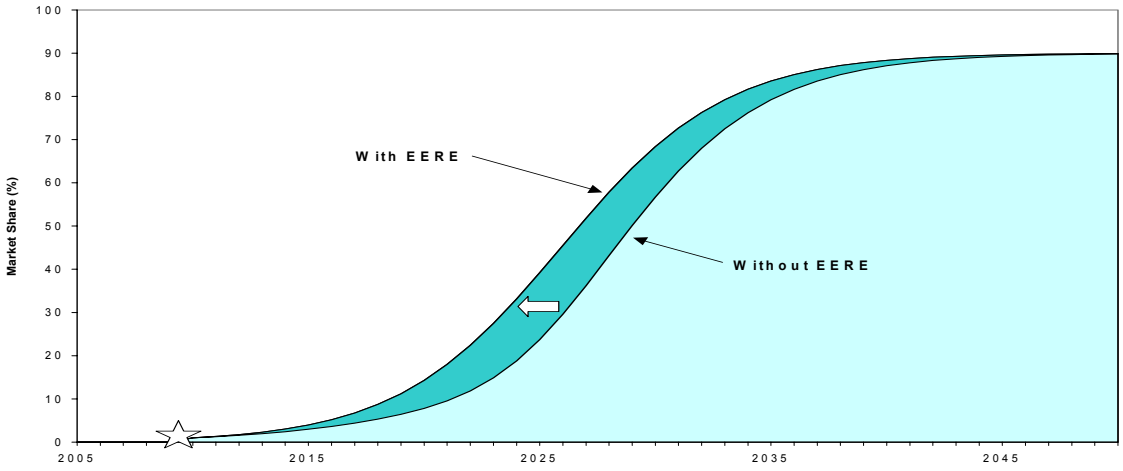

Figure 2.4b. Potential Impacts of EERE Deployment Programs on Market Penetration

*Assuming the technology, or technological characteristic, would have been developed by the private sector anyway. In some cases, technologies are so far from potential commercialization—or so risky—that private-sector firms do not invest in them. In others, the private sector lacks the market incentive to develop technology features, such as improved load-balancing for home appliances (which could improve the reliability of the electricity grid), because the markets do not provide the price signals that would generate profits from these public benefits.

Two sets of TCs are of interest: Baseline Case and Program Case. The EERE Baseline Case already includes expected private-sector advances in efficiency and renewable technologies (see **Figure 2.3**). In many cases, the specific technology characteristics are included directly in the NEMS-GPRA04; while, in other cases, they are represented through overall rates of technology improvement—and the characteristics for specific technologies must be inferred from these rates. For R&D efforts, the Program Case technology characteristics and costs are generally reflected in the program output goals.

For example, the Wind Program aims to reduce the cost of wind generation by reducing the capital costs and improving the performance of wind turbines (**Figure 2.3**). These cost and performance improvements reduce the cost of wind energy faster than occurs in the Baseline Case. For deployment activities, the individual technologies targeted are identified in program plans and related materials. For these programs, the TCs remain at their baseline levels. In both the Baseline Case and Program Case, technologies typically improve incrementally over time as research progresses. The additional R&D dollars provided by the program increases the rate of technology improvements.

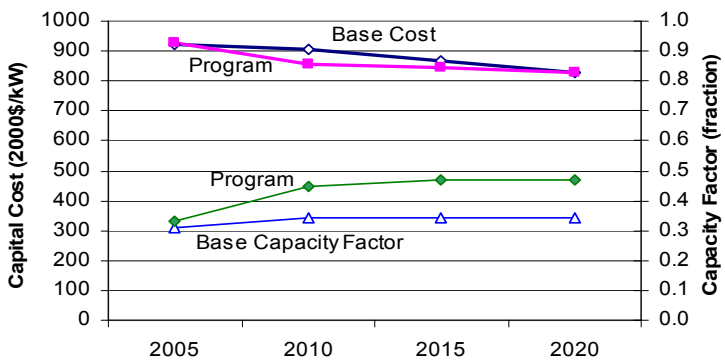

Figure 2.3. Class 4 Wind Capital Cost and Capacity Factor

Calculating direct energy and primary energy displaced. For any given technology, the "wedge" between technology sales under the Program and Baseline cases—which includes all the projected business-as-usual improvements, coupled with relative efficiencies—produce the energy savings (or displacement) attributable to the program. NEMS-GPRA04 provides projections of direct (site) energy savings from end-use programs and the corresponding primary energy reductions. Reduced electricity demand leads to reduced generation and fuel consumption by electric power producers. The marginal efficiency of power production will change over time as the mix of displaced plants shifts from existing plants to avoidance of new capacity construction. When the principal market analysis is performed outside of NEMS-GPRA04, and resultant energy savings are used as an input to the model, they are expressed in direct energy terms. The model then computes primary energy savings. (See **Box 2.2 – Energy-Economic Modeling**).

The GPRA04 analysis began under the previous EERE organization, and the programs were requested to compute the full GPRA metrics including primary energy. The guidance provided at the beginning of the analysis included a conversion factor for direct to primary

energy that reflected the anticipated shift over time in the marginal sources of energy for power production. Therefore, the supporting documentation (**Appendices B though E**) includes estimates of primary energy savings, even though the final values used in the FY 2004 budget are those from NEMS-GPRA04.

Box 2.2—Energy-Economic Modeling

Markets are fundamentally interactive. Relatively small changes in one energy market are unlikely to generate noticeable changes in other markets. In these cases, a simple "back of the envelope" estimate will suffice in estimating resulting energy savings. However, larger changes in energy markets–or a large number of small changes—can have impacts on the level of energy saved or displaced well beyond the immediate technology. A reduction in home heating and cooling costs, for instance, may result in some "take back" in the form of increased demand for heating and cooling. It also may change the mix of fuels used to produce electricity, over the time frame being analyzed here, especially if peak demand for electricity drops and fewer new power stations are needed. This will reduce the role of conventional power plants, but will also limit the development of wind and other emerging electricity sources. Similarly, a 10 percent improvement in energy efficiency in each residential energy-using device could have a noticeable impact on electricity prices and fuels.

EERE's portfolio generates significant enough changes in energy markets that it is necessary to account for these various feedbacks, up-stream impacts, and cross-market changes in order to develop better estimates of resulting benefits at the Program and EERE Portfolio levels. Mathematical models are useful to provide an internally consistent framework and baseline for the analysis. In models of this type, EERE technologies can compete with each other and with other energy technologies in these respective markets. In addition, the models can represent the extensive interactions among energy markets, such as price changes in response to changes in demand or supply levels, demand response to changes in the prices of technologies, and the potential for fuel switching. Such models also can account for a number of external factors, including fossil fuel prices, economic and demographic growth, and stock turnover.

NEMS-GPRA04 is an energy-economic model that reflects the ways in which energy is currently produced and consumed in the United States, the energy choices consumers make, and the ways in which different parts of our energy markets interact. It contains a detailed slate of energy-using technologies, including their capital costs, operating costs, efficiencies, and other technology characteristics—such as likely improvements in the technologies in the future. From those characteristics, the adoption and penetration of technologies are projected, based on algorithms that represent consumer response based on the capital, O&M, and fuel costs of competing technologies, technology efficiencies, discount rates, equipment replacement rates, and a variety of other consumer preference factors, where applicable. It is also designed to keep track of scores of possible energy paths for supplying energy to consumers. For example, the model helps discern the mix of coal, natural gas, and other energy sources likely to supply the mix of future peak and off-peak electricity loads expected.

While this model compares the costs of different paths for providing electricity and other types of energy to consumers, it also tries to reflect observed market factors beyond price. The model has assumed discount rates used by consumers in making energy investments, which vary substantially by market segment and technology. It also builds in "typical" lag times for market for supplies of new technologies or energy resources and many of the other "market frictions" that can dampen market acceptance of a new technology.

Integrating models differ enormously in terms of the amount of market information included, depending on both the purpose of the model and the data actually available. In general, longer-term modeling must be based on simpler representations of individual energy markets. Some aspects of energy, such as regional variations in energy supplies or prices, can be incorporated into many models—if the information is available at a regional level. The breadth of EERE's portfolio—in terms of markets addressed, geographic regions, and time frame—limit the extent to which any one model, including NEMS-GPRA04, can be relied on in estimating program benefits. Indeed, for much of EERE's portfolio, however, NEMS-GPRA04 does not reflect the level of detail needed here to provide a good understanding of how a particular EERE technology might fare. In these cases, some of the analysis must be undertaken off-line, or outside of the model. In practice, a significant amount of market-specific information must be developed outside or "off-line" from the model. Benefit estimates developed outside of these energy-economic models are reduced by judgment to account for market feedbacks.

Calculating carbon equivalent emissions reductions. Similar to primary energy, carbon emissions are computed using NEMS-GPRA04, based on energy savings that result either from an internal estimation of program impacts on energy markets or from an external analysis of direct energy savings that is used as an input to the model. Much of the growth in electricity generation is expected to be produced from relatively low-carbon natural gas, rather than higher-carbon coal. The resulting carbon emission factors for electricity reflect this lower and changing carbon content for marginal electricity sources. The GPRA 2004 documentation of program analyses also includes estimates of carbon emissions in addition to estimates for primary energy. These are based on direct energy savings and carbon emission factors (the amount of carbon contained in the fuel) that are provided for each fossil energy source and for electricity.

EERE's ability to apply these methodological approaches varies considerably by program, depending on the availability and cost of market data, the ability to assess public and private-sector technology contributions, and current capabilities to reflect specific market conditions in energy models available to EERE.

Other factors have been considered to augment EERE's current analysis. Some of these have been deemed to not have a significant impact on the resulting estimates of benefits and, therefore, have been excluded from the analysis.[8] In some cases, however, empirical evidence or energy-model assessments, or improved data or methodologies, would produce more accurate or robust (i.e., less sensitive to assumptions) benefit estimates. EERE is currently identifying important areas of improvement and prioritizing those improvements with respect to their ability to improve the consistency of EERE's benefit estimates.

Step 2: Program and Market Inputs

In Step 2, program goals and salient target market characteristics are developed as inputs to modeling the benefits estimation in Step 3. The effort required under Step 2 varies considerably, depending on the form in which NEMS-GPRA04 utilizes this information. It ranges from the compilation of technology goals to detailed market analyses that produce technology penetration rates—and, in some cases, delivered energy savings.

NEMS-GPRA04 contains a detailed technology representation of electricity markets, most residential and commercial end uses, and vehicle choice—but uses trends for the representation of industrial efficiency improvements and existing residential shell retrofits. In those first cases where the NEMS-GPRA04 includes both explicit representation of the program technology and target-market characteristics, this step simply requires (1) confirming representation of the target market in the Baseline Case and (2) providing the program goals in a format consistent with the

[8] For example, when market analysis indicated that there is no substantial difference between future average and marginal electricity prices, EERE chose to not include this additional market consideration in its guidance and benefits analysis. By comparison, it turned out that there is a significant difference between average and marginal carbon emissions from electricity production, and ignoring this difference would overstate the climate benefits of EERE technologies. Being able to ignore some market details helps reduce the complexity and cost of benefits analysis, but requires an up-front investment to assess which details can be safely ignored.

model. Any updated market characteristic information is used to adjust NEMS-GPRA04 for both the Baseline Case and the Program Case. The program goal information is used to adjust the commercialization date, technology characteristics, or market penetration rate for the Program Case. The comparison of market technology introduction and market penetration rates, with and without the program goal—and the calculation of the energy displaced—occur within NEMS-GPRA04.

For much of EERE's portfolio, additional "off-line" analyses are needed to translate information about program technology and market characteristics into usable modeling inputs. This off-line Step 2 analysis can range from spreadsheet calculations to the use of market-specific models to assess technology or market features that cannot be adequately represented in a broad energy-economic model or to translate program goals into the variables used in the modeling. In general, the most detailed off-line analyses are performed for the Industrial Technologies Program, Weatherization and Intergovernmental Program (WIP), Federal Energy Management Program (FEMP), and portions of the Building Technologies Program, along with the heavy-truck portion of the FreedomCAR and Vehicle Technologies Program. These off-line analytical approaches are tailored to the characteristics of the program and target market being analyzed; but, in any case, are conducted within the overall guidance provided through the GPRA benefits estimation process.

Where NEMS-GPRA04 does not include technology-by-technology information (e.g., cost, date of availability), or specific market-penetration rates, it is often necessary to translate program goals into the more general rates of technology improvement used by the model. This is true for the Industrial Technologies Program and some elements of the Building Technologies Program, where numerous specific technology advances or market deployment efforts will accelerate overall efficiency improvements in buildings or factories specified in the Baseline Case.

The market applications for EERE technologies are often very specific, and resulting energy savings for a given technology can vary significantly from one application to another. For example, the impact of upgrading building codes can vary significantly (due to differences in climate and in existing building-code standards) and therefore require analysis at the State level. The Building, Industrial, and WIP programs are most likely to require tailored analytical approaches that address these submarkets.

Off-line analysis also can be required for targeted submarkets that are simply not included in NEMS-GPRA04—or for which the resulting technology use is not fully market-driven. Examples include the Federal sector (addressed by FEMP) and the Low-Income Weatherization Assistance Program, in which home efficiency improvements are directly purchased by the Federal Government.

Finally, supporting "off-line" analysis can be required where market functions are not well represented in a full energy-economic model. For example, consumer willingness to pay a premium for electricity produced by environmentally friendly technologies is not represented within the electricity market in NEMS-GPRA04; and, therefore, another model specifically designed to analyze this market is used. Also, programs designed to help overcome institutional barriers to efficiency adoption are often difficult to represent in market-based models.

Because estimating the benefits of achieving program performance goals requires the ability to realistically assess the extent to which future energy markets might adopt the technology and market improvements developed by EERE programs, the following features are explored in these external analyses:

Target Markets. New technologies will not necessarily be well suited to all applications served by existing markets. Especially in early years, technologies may occupy niche markets. In some cases, initial markets may be geographically limited as well. Where NEMS does not represent these submarkets explicitly, it may be necessary to develop off-line estimates of the applicable market share for the technology being developed, at least in the early years.

Stock Turnover. Analyses of the market adoption of new technologies must consider the rate at which the specific type of energy-using or -producing capital equipment is replaced, in addition to the growth rate of the overall market. Even when a technology is suitable and cost-effective for a percentage of a market, it may take a decade or more for the capital stock in that portion of the market to retire and be replaced. Particularly attractive new technologies might accelerate that turnover. EERE includes this potential for early retirement only when market evidence suggests that the technology improvement is significant enough to overcome typical hurdle rates to new investment. Although stock turnover fluctuates with business cycles, EERE does not incorporate business cycles into its Baseline or Program cases. As a result, nearer-term benefits, in particular, may differ from those expected. Modeling stock turnover is crucial to estimating benefits accurately for both new technologies and deployment programs.

Next Best Technology. Where this representation is implicit (in a technology improvement index, for instance), the Baseline Case improvement must be translated into improvement rates for a specific set of technologies. This set of baseline technologies is then used to assess the specific markets in which the EERE technology might be competitive in different timeframes.

Market Penetration. Over time, new technologies typically make their way into markets—and, therefore, affect energy use—gaining in share of new sales as consumers learn about the availability of the product, manufacturing capacity grows, and product prices fall with economies of scale and learning.[9] While price helps determine whether a product is cost-effective on average, energy prices vary by type of customer and region, so that new products may be cost-effective for some customers before they are generally cost-effective (a niche market). Price, or cost-effectiveness, is often not the only aspect of the new technology or deployment program that shapes its market acceptance. Many nonprice or cost factors affect consumer behavior. Analysts may adjust models and analyses for such factors using judgments based on better information on expected consumer behavior.

[9] See Adam B. Jaffe, Richard G. Newell, and Robert N. Stavins, "Energy-Efficient Technologies and Climate Change Policies: Issues and Evidence," Climate Issue Brief No. 19, *Resources for the Future*, Washington, D.C. (December 1999).

Only for R&D programs does EERE assume the impact of the program is to accelerate the commercial introduction of a technology—assuming that the technology, or technological characteristic, would have been developed by the private sector anyway. In some cases, technologies are so far from potential commercialization—or so risky—that private-sector firms do not invest in them. In others, the private sector lacks the market incentive to develop technology features (such as improved load-balancing for home appliances) that could improve the reliability of the electricity grid. This is because the markets do not provide the price signals that would generate profits from these public benefits. In some cases, that may be the only effect.

As an example, the off-line analysis for the Industrial Technologies Program uses a spreadsheet model that provides several possible market penetration curves. A curve is chosen by the analyst, based on specific information from possible R&D partners, comparison of the new technology to similar technologies, or his or her expert judgment. The benefits guidance for Industrial benefits estimation includes historic penetration curves for 11 technologies and offers the analyst five choices of penetration curve shapes. The five choices are accompanied by detailed data on technology equipment, financial, industry, regulatory, and impact characteristics to aid in making the choice. In addition to choosing the shape or the penetration curve, the analyst chooses the year—after all pilot testing and demonstration phases—the new technology is expected to enter the market.

Through the use of specialized spreadsheets or other models, or through the use of NEMS, program analysts produce estimates of market penetration and direct energy savings. However, these "off-line" estimates are not the final/official benefits estimates. These off-line estimates are integrated within the NEMS-GPRA04 model as the final part (Step 3) of the process.

Through the use of a specialized spreadsheet or other models, or through the use of NEMS, the market analysts produce estimates of market penetration and direct energy savings. For GPRA04, they also produced benefits estimates.[10] These, however, are not the final/official benefits estimates. The resulting technology and market data and assumptions are integrated within the NEMS-GPRA04 model, as in the final step of the process.

Step 3: Program and Portfolio Benefits Estimates

The final step for estimating the impacts of EERE's FY 2004 Budget Request begins by each EERE program being modeled separately within NEMS-GPRA04 to the extent possible. In each program NEMS-GPRA04 run, only the modeling assumptions related to the outputs of the program being analyzed are changed. The modeling assumptions related to the other EERE programs remain as they were in the EERE Baseline Case. Each program is modeled separately

[10] As EERE's benefits analyses are streamlined under the new organization, the step of producing initial benefits estimates for each program will be eliminated, and information about key market factors will be incorporated directly into the integrated benefits analysis. Key market information will be updated as market conditions change or new market information becomes available. In addition, benefits out to 2050 will be modeled using MARKAL. For programs that cannot be modeled using NEMS or MARKAL, additional tools and judgment will again be used regarding how to integrate such program benefits into the overall analysis.

to derive estimated energy savings without the interaction of the other programs. The results from the program NEMS-GPRA04 runs are then compared to the Baseline Case to measure the individual benefits of the EERE program being analyzed.

A few of the programs were modeled in groups, and then the joint benefits were allocated to the individual programs. This was primarily due to the legacy of the previous EERE organization. The renewable electricity-generation technologies (solar, wind, hydropower, geothermal, and biomass gasification) were one such group. In addition, fuel cell vehicles (from the HFCIT Program) were modeled along with hybrid vehicles and diesel vehicles (from the FCVT Program) and with natural gas vehicles (from WIP). The grouping likely reduces somewhat the benefits of each program, because they compete in the same markets. The detailed representation of how each of the programs was modeled in the EERE Benefits Case is described in **Chapter 4**.

For programs modeled using NEMS-GPRA04 directly, the Benefits Case is computed by changing the assumptions representing the program outputs; i.e., the goals or performance targets of the program, such as reducing low wind-speed turbine costs and improving their performance. The R&D programs are represented in NEMS-GPRA04 through changes in technology characteristics that represent the program goals, to the extent possible. Activities designed to stimulate additional market penetration of existing technologies generally were modeled through changes in consumer hurdle rates or other appropriate market-penetration parameters, with the goal of representing the market share targeted by the program.

Program impacts that cannot be easily modeled in detail using NEMS-GPRA04 are estimated using a variety of tools, as described in Step 2. These supporting analyses typically provide either estimates of market penetration and per-unit energy savings, or total site energy savings that are then used as inputs to NEMS-GPRA04. In cases where the off-line analyses produce a direct estimate of site energy savings, this information is also incorporated, with adjustments, in NEMS-GPRA04 in order to calculate primary energy savings.

Another challenge in estimating benefits is the potential for program results—individually, or in combination—to be significant enough that market responses and interactions need to be considered. Past EERE experience indicates that failure to reflect market responses tends to overestimate some program benefit levels, even if the overall impact on the EERE portfolio is small. NEMS-GPRA04 takes these feedbacks and interactions into account, which off-line tools generally do not.

As such, in many cases,[11] these off-line results are adjusted based on the judgment of the integrated modeling team before using these as inputs into NEMS-GPRA04. As a general rule, the program estimates were reduced in these cases, rather than implemented at the full savings level in the models.

[11] An example exception is the Weatherization Program, which involves direct field application of energy-savings improvement.

The integrated modeling team selected a discounting of 30 percent to be conservative about these programs that could not be economically evaluated.[12]

Once each of the programs (or group of programs) was represented individually within NEMS-GPRA04, the benefits of EERE's portfolio were estimated by combining all of the programs assumptions into one scenario. The purpose of this approach is to analyze all EERE's programs in a consistent economic framework and to account for the interactive effects among the various programs. Estimates of individual EERE program energy savings cannot be simply summed to create a value for all of EERE, because there are feedback and interactive effects resulting from (1) changes in energy prices resulting from lower energy consumption and (2) the interaction among programs affecting the mix of generation sources and those affecting the demand for electricity.

Detailed energy projections from the EERE Baseline and Portfolio Benefits Case are in **Appendix A**.

[12] Program energy savings that were estimated outside the integrated model and then used as exogenous inputs to NEMS were discounted, primarily in an attempt to account for integration effects. In most cases, these estimates are derived for single program activities without consideration of other activities within the same program. The 30 percent reduction reflects the overall average decrease in individual program impacts for those programs that can be modeled in NEMS for the portfolio estimates. As such, 30 percent is used as a "rule of thumb" for the balance of the portfolio that cannot be modeled in NEMS-GPRA04 directly. The impact of an activity, such as the industrial Best Practices Program, is generally developed from a Baseline Case that does not include other activities; in this case, other industrial program impacts. In addition, the cost-effectiveness of a technology—and, therefore, its adoption rate—will be affected by the adoption of other technologies. As a result, estimated savings for a single activity is likely to be overestimated. In contrast, program activities that can be modeled in NEMS-GPRA04 based on technology characteristics, both types of interactions are captured internally. Therefore, for single-activity programs estimated outside NEMS-GPRA04, a discount factor is applied to the off-line estimates to make them more comparable. A secondary purpose in discounting the off-line savings is that, in many cases, an economic analysis was not conducted; and, therefore, the savings were not fully justified. Discounting such savings provides a rough but conservative way to account for the uncertainties inherent in the estimates.

CHAPTER 3

FY 2004 BENEFITS ESTIMATES

The Office of Energy Efficiency and Renewable Energy (EERE) estimates expected benefits for its overall portfolio and for each of its 11 programs. Benefits for the FY 2004 budget request are estimated for 2005-2020. The year 2020 is the last date for which an independent reference forecast was available at the time of this analysis.

Benefits estimates are intended to reflect the value of program activities from 2005 forward. These estimates do not include the impacts of past program success, nor technology development or deployment efforts outside EERE's programs. This distinction is difficult to implement in practice, as many research and deployment activities provide continuous improvements that build on past success; and because EERE programs are leveraged with private-sector and other government efforts.

Outcomes and Benefits Metrics

The energy efficiency improvements and additional renewable energy production facilitated by EERE's programs reduce the consumption of traditional energy resources. Reducing energy consumption affords the Nation a number of economic, environmental, and energy security benefits.[1] The extent of these benefits depends on factors including which energy sources are reduced, the costs of the new technologies, and the emissions performance of the energy technologies used. Different EERE portfolios would produce a different mix of benefits, even if the overall level of primary energy savings were the same.

The public benefits resulting from these reductions in the use of traditional energy resources take many forms. Environmental improvements, for instance, can include reductions in local, regional, or global air emissions; reduced water pollution; noise abatement, etc. These public benefits are typically difficult to measure directly, and some aspects are not quantifiable. EERE has developed a set of *indicators* intended to provide a sense of the magnitude and range of the benefits its programs provide the Nation. EERE estimates benefits for the following categories:

Primary Outcome:

Energy Displaced: Displaced energy (or energy savings) is calculated as the difference in nonrenewable energy consumption with and without the technologies and market improvements developed by EERE programs. Energy savings are measured on a primary basis, accounting for the energy consumed in producing, transforming, and transporting energy to the final consumer. Energy savings from underlying, private-sector improvements in technologies are not counted.

[1] This is a categorization of EERE's benefits estimates based on the framework developed by a National Research Council (NRC) committee. The framework is described in more detail in the Introduction.

Primary Benefits:

Economic Benefits: Economic benefits are the potential for EERE technologies to make energy more affordable, increase economic productivity and GDP, reduce the impact of energy price volatility on the U.S. economy, and improve the balance of trade.

EERE currently utilizes one primary measure related to affordability:

Energy-expenditure savings: Energy-expenditure savings are calculated as the difference in total consumer energy bills, with and without the availability of technologies and market improvements developed by EERE technologies. This is a gross savings estimate, as it does not include the incremental cost to end users of acquiring the new technology. The EIA NEMS model does not currently have the capability to provide net costs.

Energy efficiency improvements and increased use of nonfuel renewable energy reduce energy bills in two ways. Consumers who make energy efficiency or renewable energy investments benefit directly through reduced purchases of energy (quantity component). In addition, the lower demand for energy reduces the price of energy for all consumers (price component). Both elements are included in this metric.

Environmental Benefits: Environmental benefits include lower carbon, SOx, NOx, and other air emissions associated with renewable energy use and energy efficiency improvements, improvements in water quality, reductions in noise, a reduced "footprint" for energy exploration and development, and the health and ecological implications of each of these.

Of these, EERE currently estimates only the impacts of its programs on carbon emissions:

Carbon savings: Carbon savings (i.e., emission reductions) are calculated as the difference in the level of U.S. energy-related carbon emissions with and without the availability of EERE technologies and market improvements.

Carbon emission reductions result from the reductions in fossil fuel consumption when these new supply (renewables) and demand (energy-efficient) technologies are used in the market. As with the energy-savings metric, emission reductions count the effect of upstream energy savings in producing, transforming, and transporting energy to the end user.

Security Benefits: Security benefits include improvements in the reliability of fuel and electricity deliveries, reduced likelihood of supply disruptions, and reduced impacts from an energy disruption.

EERE contributes to these security gains by reducing U.S. reliance on imported fuels, increasing the diversity of domestic energy supplies, increasing the flexibility and diversity of the Nation's energy infrastructure, reducing peak demand pressure on that infrastructure,

and providing backup energy sources in the event of outages. Of these aspects of energy security, EERE has developed indicators related to concerns about fuel imports and the reliability and diversity of electricity supplies:[2]

1. **Oil savings:** Oil savings are calculated as the difference in total U.S. oil consumption with and without EERE technologies and market improvements.
2. **Natural gas savings:** Natural gas savings are calculated as the difference in total U.S. natural gas consumption with and without EERE technologies and market improvements.
3. **Electricity generation capacity:** Electricity-generation capacity impacts are calculated variously as the difference in renewable power-generating capacity (capacity additions); the amount of electricity capacity displaced by efficiency improvements (displaced capacity); or the amount of distributed generation, with and without EERE technologies and market improvements.[3]

The natural gas and electricity capacity security metrics are new for EERE this year. A natural gas measure was added to reflect the growing importance in the U.S. energy mix of natural gas imports. The electricity-generation capacity metric reflects increasing concerns about the adequacy of traditional, centralized electricity systems to provide reliable electricity in the years and decades ahead.

In interpreting these results, it is important to remember that while the benefits of efficiency and renewable technologies are multifaceted, they are not always distinct or additive. Improvements in balance-of-trade or economic productivity, for instance, are contributory to improved GDP and not additional to improved GDP. Nonetheless, identifying the various types of economic or other contributions can help relate EERE's portfolio to various economic or other policy concerns.

Each of these metrics is ideally measured as a net benefit (e.g., energy bill savings, less the cost to the consumer of investing in the efficient or renewable technology; any negative, as well as positive, environmental impacts). EERE's current modeling tools lack the ability to back out some of these types of costs. Carbon emission reductions, as well as oil and natural gas savings are calculated on a net basis (e.g., accounting for cases in which EERE programs tend to increase rather than decrease use or emissions); while consumer-expenditure estimates do not reflect the costs to consumers of purchasing more efficient or cleaner technologies.[4]

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[2] The inclusion of reliability improvements within the security category was part of the NRC suggestions on how to structure the types of EERE benefits. The 2003 blackout in the Midwest and New England indicates the extent to which security and reliability are intertwined.

[3] These measures are not additive and are not the same as a measure of peak load reduction for conventional electricity or of improved reliability. Renewable capacity additions are not equivalent to capacity additions avoided because of differences in capacity factors and coincidence of renewable generation at system peak (i.e., peak electricity generation output of wind, for example, may not coincide with the peak demand of the utility system to which it supplies power).

[4] EERE is in the process of adopting an additional economic model, which is able to provide estimates of net economic costs. This model, MARKAL, will also estimate benefits out to 2050.

Portfolio Benefits

Table 3.1 presents the economic, environmental, and security benefits of EERE's overall portfolio of investments in improved energy-efficient technologies, renewable energy technologies, and assistance to consumers in adopting these technologies.

Table 3.1. Annual EERE Portfolio Benefits for FY 2004 Budget Request for Selected Years

EERE Portfolio Benefits	2005	2010	2020
Energy Displaced (quadrillion Btu)	0.6	2.3	8.7
Economic Benefits:			
▪ Energy-expenditure savings (billion 2000 dollars)	8.5	31.2	101.8
Environmental Benefits:			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	10.6	38.9	151.0
Security:			
▪ Oil savings (quadrillion Btu)	0.2	0.7	3.3
▪ Natural gas savings (quadrillion Btu)	0.4	1.2	3.8
▪ Renewable electric-generating capacity (gigawatts)	1.5	7.2	39.4

Energy Displaced: EERE's portfolio significantly dampens the expected growth in conventional energy consumption. Absent the results of EERE's programs,[5] energy use is expected to grow by nearly 21 quads from 2005 to 2020, to about 121 quadrillion Btus of energy. EERE's investment portfolio would reduce nonrenewable energy consumption by nearly 9 quadrillion Btu by 2020, or more than 40% of the expected incremental growth in energy demand over this time period (see **Figure 3.1**).

These estimates account for interactions among program results. While some program activities reinforce each other to produce larger benefits than would be evident from each program's individual efforts, programs compete for the same markets in other cases. For example, the various renewable technology programs compete in the electricity-generation market. In addition, activities being funded by some programs reduce the potential market for technologies being developed in other programs. As an example, reductions in electricity demand due to efficiency improvements reduce the size of the generation market and, therefore, the market opportunity for renewable-generation technologies. The overall effect of these interactions is to reduce EERE benefits in 2020 by about one-half quad compared to the sum of the individual program benefits (i.e., Program Case, see **Figure 3.2**).

Economic Benefits: The energy savings resulting from these efficiency and renewable energy contributions are estimated to reduce annual consumer energy expenditures in 2020, expressed in real 2000 dollars, by $102 billion relative to the baseline projection of $880 billion (**Figure 3.3**), or about 12 percent of the nation's expected energy bill.

[5] See Chapter 1 for information on how EERE's "no-program" Baseline Case is developed.

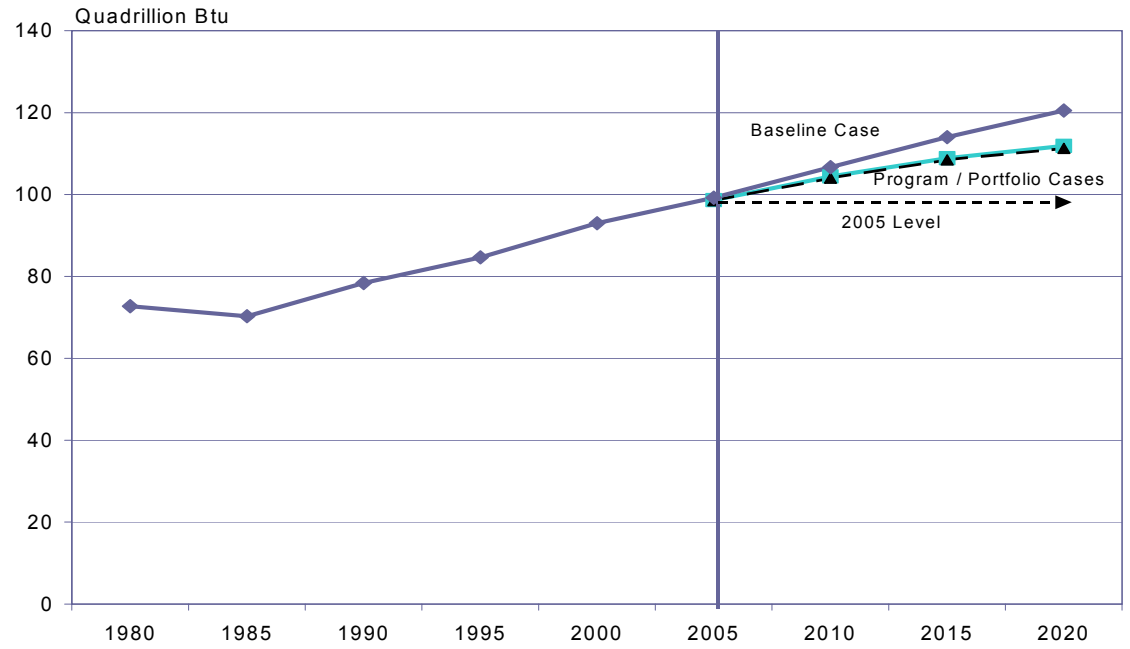

Figure 3.1. U.S. Nonrenewable Energy Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

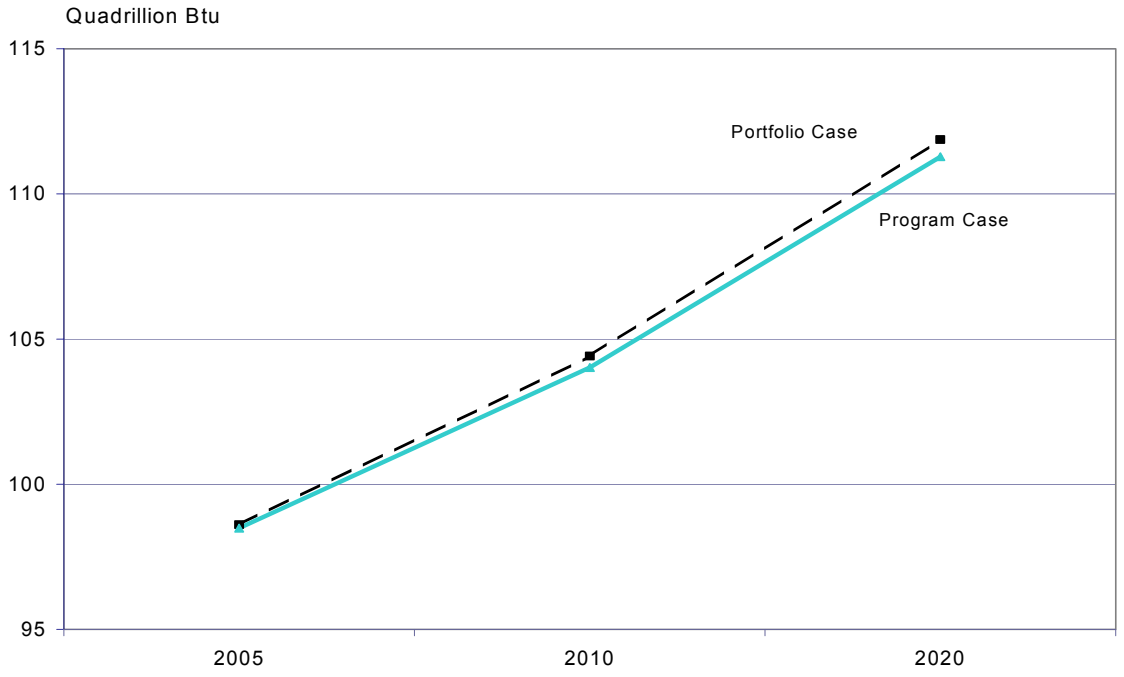

Figure 3.2. Comparison of Program and Portfolio Nonrenewable Energy Consumption Estimates, 2005, 2010, and 2020 (quadrillion Btu)

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 1.3, Web site: http://www.eia.doe.gov/emeu/aer/contents.html.

While these energy bill savings appear to be large, they represent both reduced energy purchases and lower energy prices resulting from reductions in demand. They also exclude incremental costs to end users of acquiring the new technology because the EIA NEMS model does not currently have the capability to determine this. Lower energy demand dampens fuel costs and reduces the need for expensive new energy infrastructure expenditures. Lower energy prices improve affordability for all consumers, including those who make no additional efficiency or renewable investments as a result of EERE's activities.

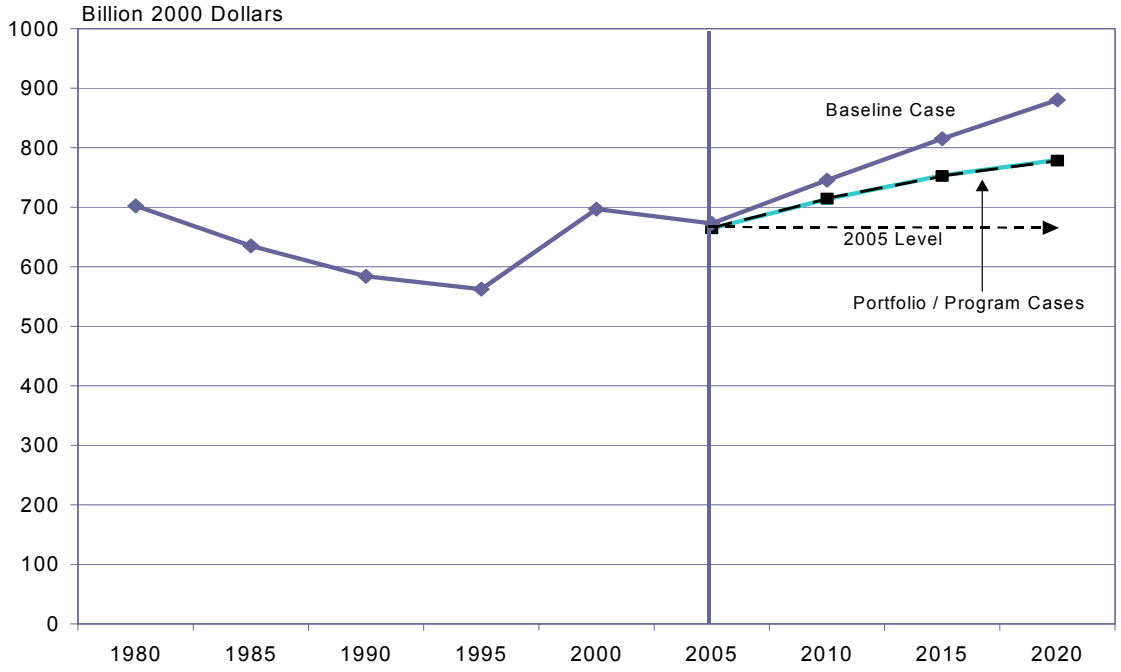

Figure 3.3. U.S. Total Energy Expenditure, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-1995: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 3.4 and Table E1, Web site http://www.eia.doe.gov/emeu/aer/contents.html.
Data Source, 2000: Energy Information Administration, *Annual Energy Outlook 2002*, DOE/EIA-0383 (2002) (Washington, D.C., December 2001), Supplemental Table 20.

EERE's Weatherization Grant Program specifically targets energy savings and energy bill reductions for low-income families. At the FY 2004 request level, the program directly funds weatherization of nearly 230,000 low-income-family homes per year, including homes weatherized by additional governmental and utility funding. In FY 2004, these homes save each year an average ranging from $3,429 in the Midwest to $1,814 in the West. By 2020, this will translate into about $917 million in annual energy bill savings for low-income families.[6]

[6] U.S. Department of Energy, Energy Efficiency and Renewable Energy, *Methodological Framework for Analysis of GPRA Metrics: Application to FY04 Projects in BT and WIP*," PNNL 14231 (April 2003), pp. B-27–B-31. Because homes that are weatherized continue to save energy in the years following the weatherization, the total number of homes saving energy due to this program grows over time, even when program funding remains constant.

Environmental Benefits: Annual carbon dioxide emissions are projected to be 151 million metric tons (carbon equivalent) less than the 2020 baseline projection of 2,073 million metric tons, a reduction of about 7.5% (**Figure 3.4**) or 39% of the expected increase from 2005 to 2020. By 2010, the projected reduction will be about 39 million metric tons, which could provide about one-third of the targeted 2012 carbon reduction under President Bush's Climate Change Initiative.

Although not quantified here, EERE's portfolio also contributes toward improved regional and local air quality through reduced SO_2 and NOx emissions from fossil energy consumption (SO_2 reductions in the utility sector are likely to lower permit prices rather than reduce net emissions in this sector). The portfolio also provides state and local governments with additional options for meeting Clean Air Act ambient air quality standards. For instance, the Clean Cities activity in WIP facilitates local purchases of alternative-fuel vehicles.

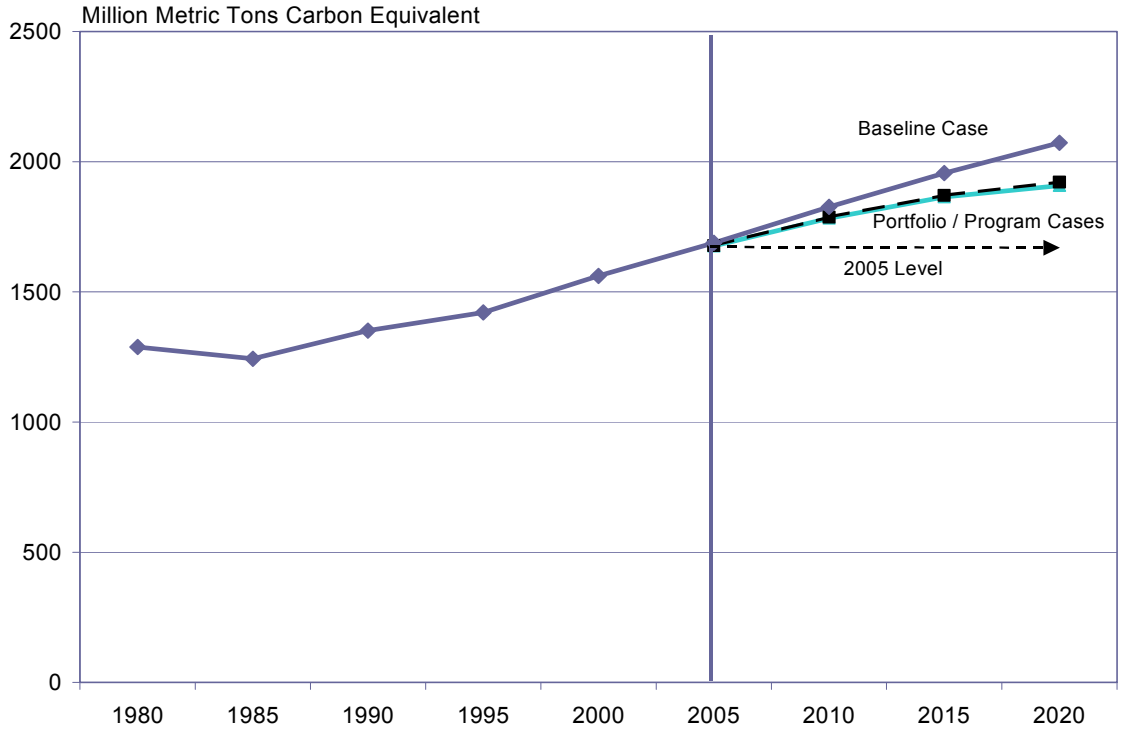

Figure 3.4. U.S. Carbon Dioxide Emissions, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 12.2, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

Security Benefits: The EERE portfolio is expected to reduce annual oil consumption by 3 quadrillion Btu from the 2020 baseline of 52 quadrillion Btu (**Figure 3.5**), or about 1.6 million barrels of oil per day (about 31% of expected growth in oil demand between 2005 and 2020).

While EERE's portfolio has elements that increase (as well as decrease) natural gas consumption; on balance, EERE's portfolio is expected to reduce annual natural gas

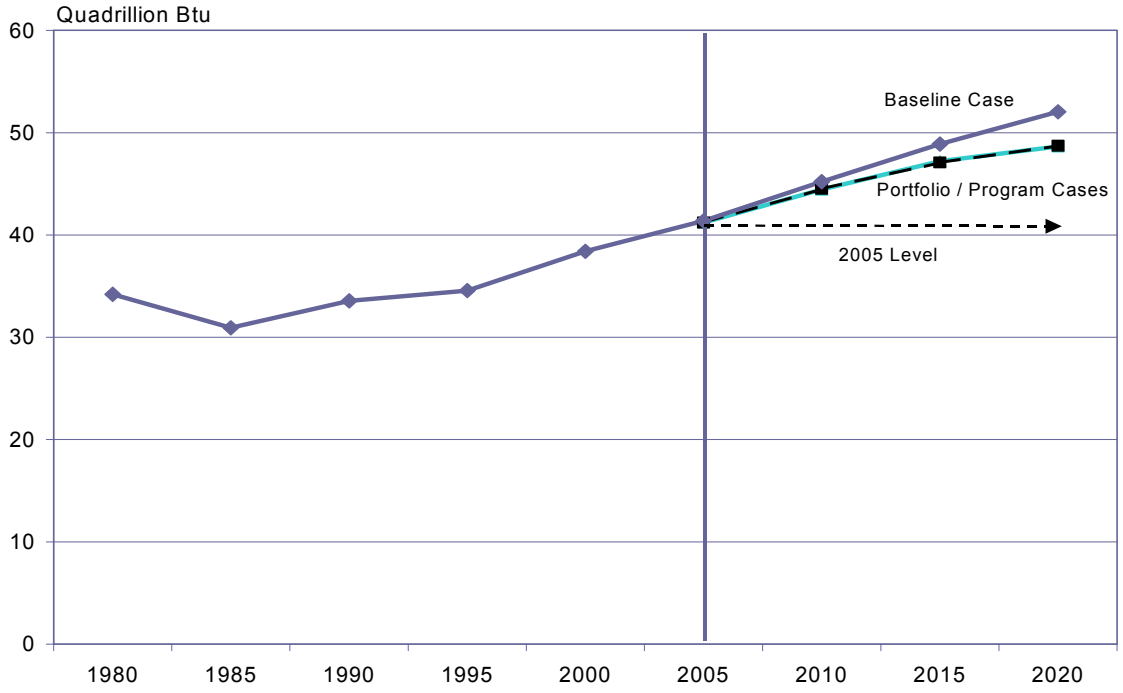

Figure 3.5. U.S. Oil Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

consumption by 4 quadrillion Btu from the baseline of 35 quadrillion Btu (**Figure 3.6**) in this time frame.[7] While EERE does not estimate the portion of natural gas savings attributed to imported natural gas supplies, supplies from countries other than the United States and Canada may be the marginal sources of natural gas for meeting any future growth in demand.

Capacity Benefits: When evaluated as part of a portfolio, energy efficiency improvements developed by EERE reduce the market opportunity for the development of new renewable resources by reducing the demand for additional energy capacity. Even with these reductions, EERE projects that renewable energy technologies will provide significantly larger electricity capacity additions than in the Baseline Case by 2020. As shown in **Figure 3.7**, renewable energy capacity additions are projected to grow by an additional 40 GW compared with the Baseline Case by 2020. Moreover, if some of these efficiency improvements fail to materialize, it is likely that they would be partly "backfilled" by the development of additional renewable energy resources. In addition, EERE's technology programs contribute to security of the Nation's electricity supplies in another important way: through the combination of reduced peak demand for electricity (through improved efficiency or when coincident with renewable generation) and the development of on-site electricity generation sources (to mitigate bottlenecks in the electricity transmission grid).

[7] The remaining chapter of this report describes some of the limitations and omissions in the current benefits analysis, which limit EERE's ability to reflect the full benefits for each EERE program.

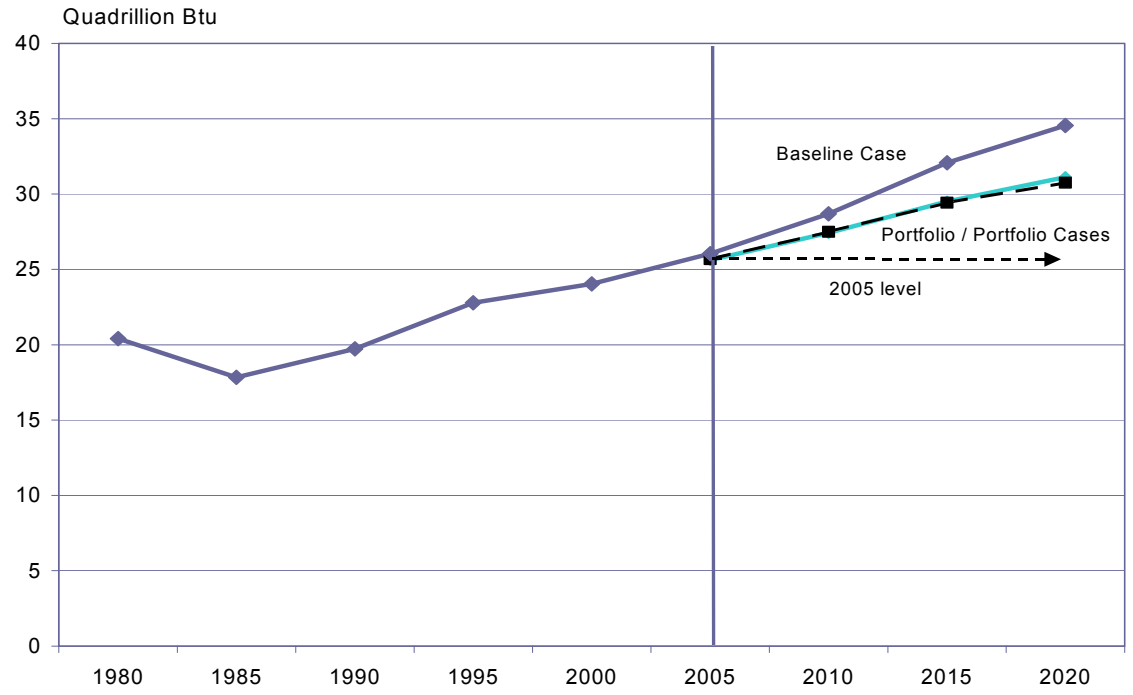

Figure 3.6. U.S. Natural Gas Consumption, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 1.3, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

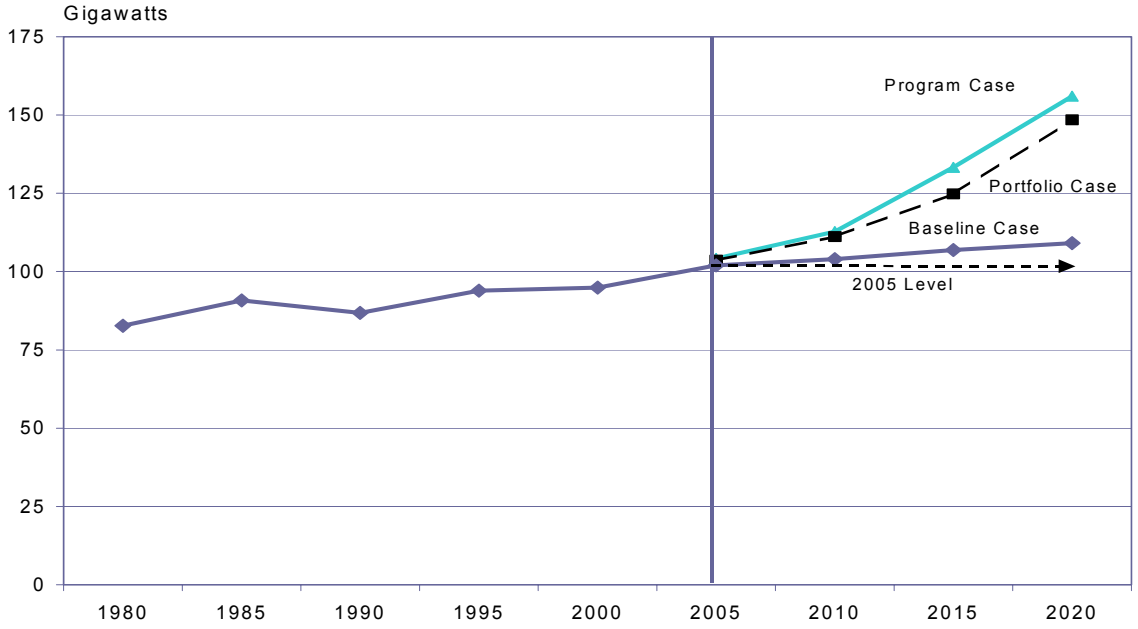

Figure 3.7. U.S. Renewable Energy Capacity, 1980-2000, and Projections to 2020: Baseline, Program, and Portfolio Cases

Data Source, 1980-2000: Energy Information Administration, *Annual Energy Review 2001*, DOE/EIA-0384 (2001) (Washington, D.C., August 2002), Table 8.7a, Web site http://www.eia.doe.gov/emeu/aer/contents.html.

Program Benefits

The remainder of this chapter is devoted to program-specific information, including program budgets and benefits. **Figure 3.8** displays the EERE program budgets for FY 2004. The largest program budget is $369 million for the WIP (Weatherization and Intergovernmental Program), which includes $284 for Low-Income Weatherization Assistance.

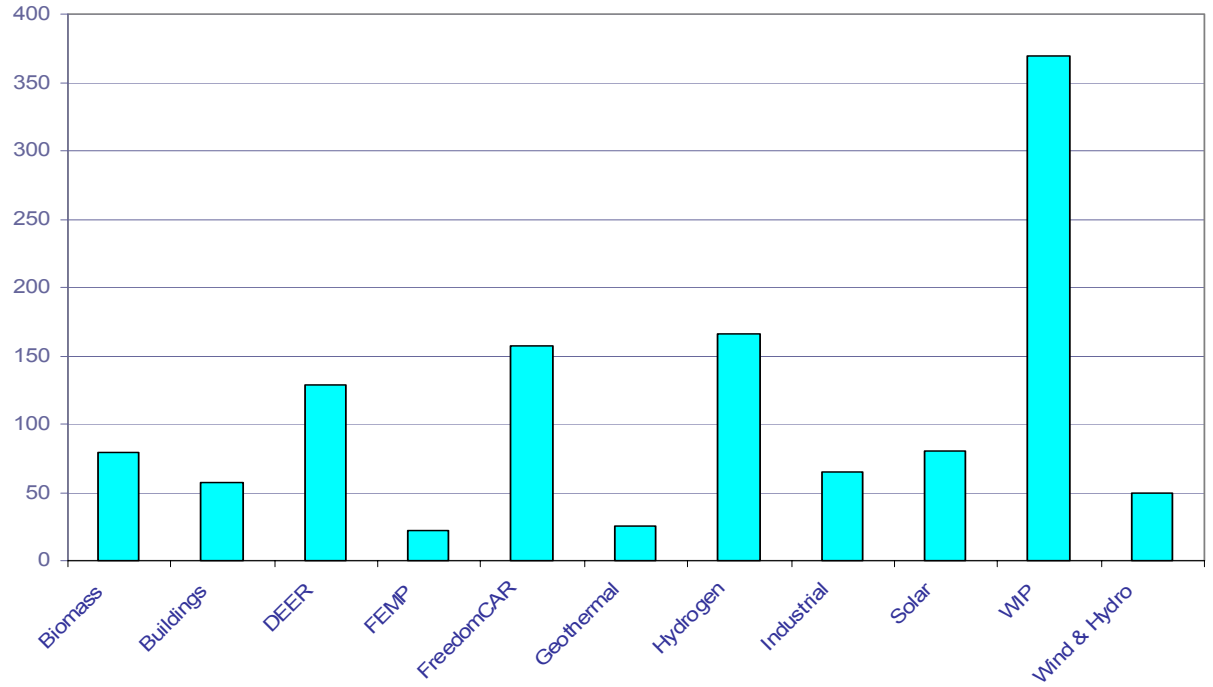

Figure 3.8. EERE Program FY 2004 Budget Requests (2000 dollars)

Source: Budget request from *FY 2004 Budget-in-Brief*, U.S. Department of Energy, Energy Efficiency and Renewable Energy, http://www.eere.energy.gov/office_eere/pdfs/fy04_budget_in_brief.pdf.

The FY 2004 estimates of benefits for the individual EERE programs are shown for 2020 in **Figures 3.9 through 3.14**. The benefits vary widely across EERE's programs, with each program providing a different level and mix of types of benefits. Nonrenewable energy savings in 2020, for example, range from 0.07 quadrillion British thermal units (Btu) for the Federal Energy Management Program (FEMP) to 2.13 quadrillion Btu for the Industrial Technologies Program (**Figure 3.9**). The differences in benefits result from a number of factors: (1) program size and target market; (2) time frames for program results; (3) primary types of benefits addressed by each program; and (4) technical potential achievable within each program and the amount of improvement already included in the baseline. Note that these estimates do not reflect the relative technical or market risk associated with these program activities. In addition, in this transition year for EERE, not all programs were able to generate new performance goals indicating the years in which they expected each technology to be ready for market in time for this analysis. As a result, portions of some program benefits are not reflected in the estimates reported here.

Once a technology enters the market, benefits increase for some period of time as (1) market shares or sales grow; (2) total market size grows to reflect increased population or GDP; and (3) the existing stock of energy-using buildings and equipment is replaced in comparison to the expected improvement in the business-as-usual case.

EERE programs differ greatly in anticipated dates of commercialization, with those programs likely to generate market results in the near term showing the largest benefits during the 15 years addressed by this analysis. In several cases, such as hydrogen-based vehicles, EERE technologies are not expected to be available until about 2020, so it was not possible to include meaningful estimates of even initial benefits levels. Those programs with a larger number of early technology introductions are likely to exhibit larger benefits.

Several EERE programs are targeted toward benefits not well reflected in any of EERE's quantified benefits metrics. For instance, the Distributed Energy Resources (DER) Program focuses on improving electricity reliability by developing electricity-generating capacity at or near the point of use (**Figure 3.14**). However, EERE does not currently have the capability of quantifying the level or value of improved reliability, or of reflecting the consumer value for reliability in estimated future market purchases. Similarly, the State Energy Grant Program funds the development of State energy plans, including energy emergency planning. This key component of homeland security is not reflected in any of the security metrics in this analysis. In the case of the Biomass Program, there has been a substantial redirection of the research toward integrated biorefineries that will produce a mix of high-value chemicals, as well as fuels such as ethanol and electric power. These are very complex systems, and EERE does not yet have an adequate modeling capability for this, as described in **Chapter 4**.

While incomplete, the results indicate both the range and approximate level of benefits available to the Nation from funding the efficiency and renewable investments in EERE's portfolio of programs. They indicate a potential for making better use of existing technologies and for accelerating technological advances to make significant changes in our energy markets.

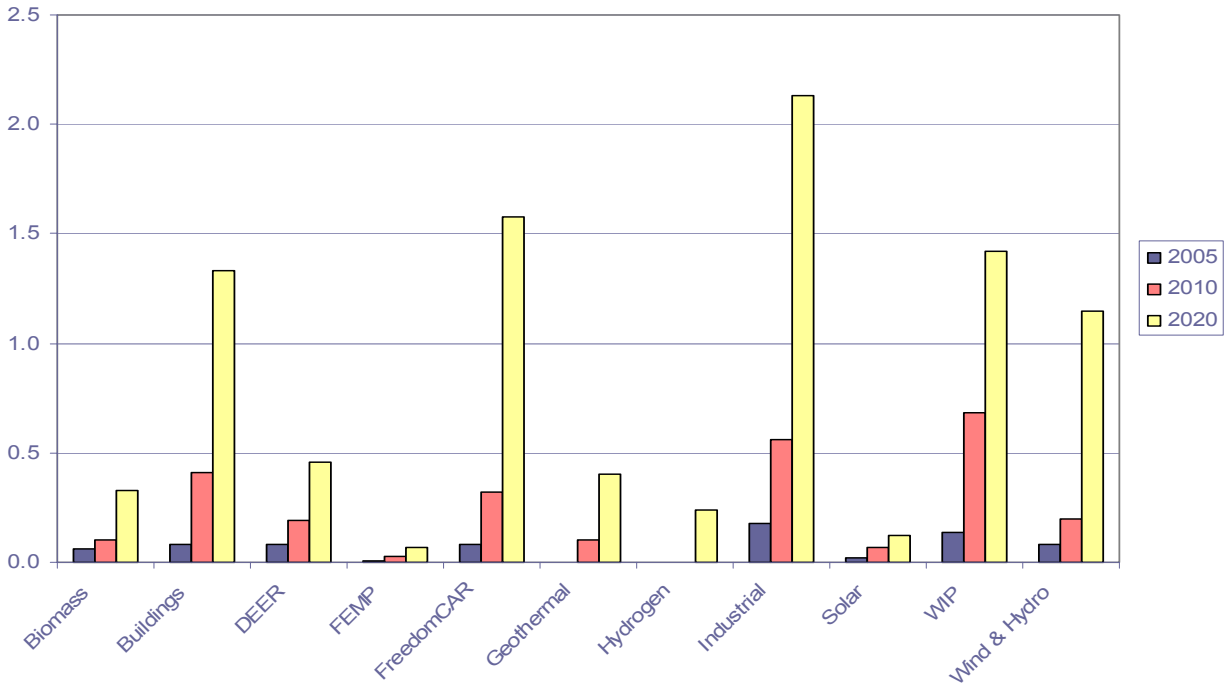

Figure 3.9. Annual Nonrenewable Energy Savings: 2005, 2010, 2020 (quadrillion Btu)

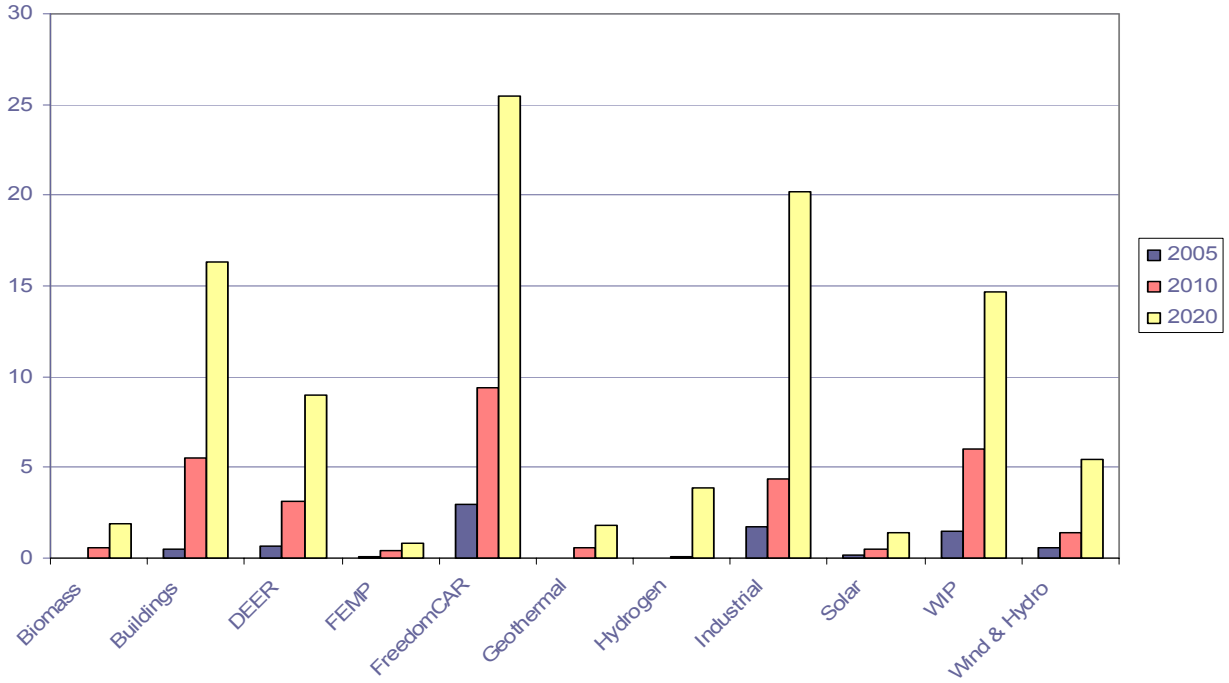

Figure 3.10. Annual Energy Expenditure Savings: 2005, 2010, 2020 (billion 2000 dollars)

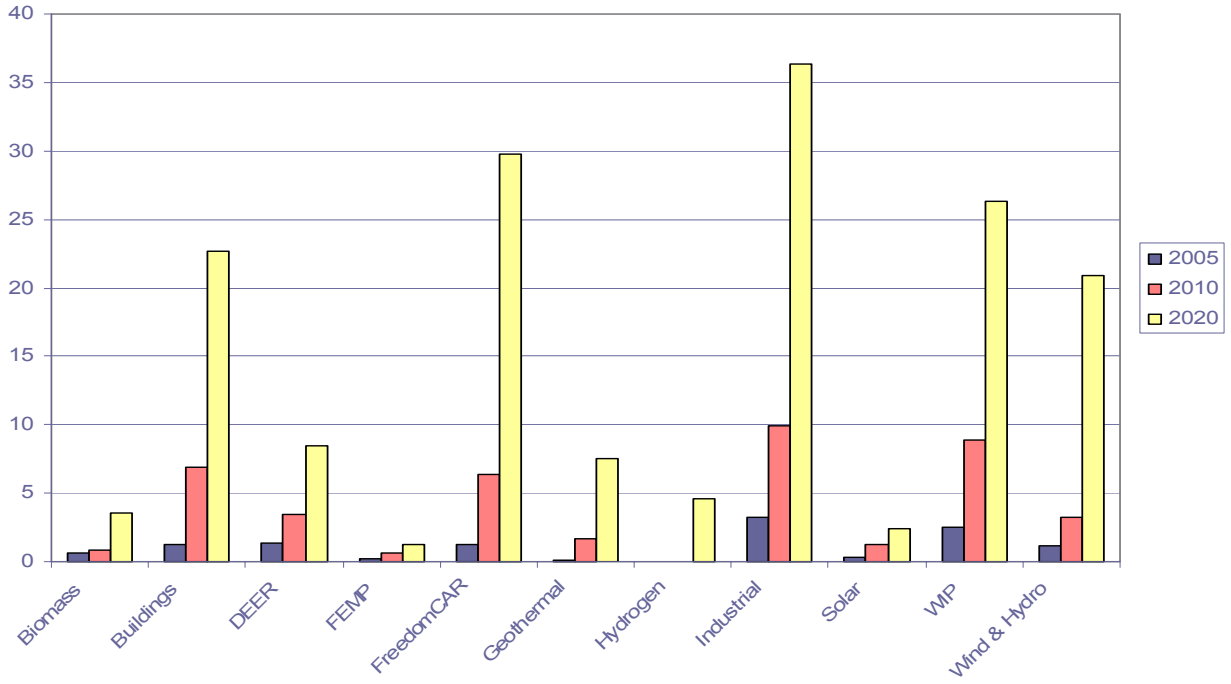

Figure 3.11. Annual Carbon Dioxide Savings: 2005, 2010, 2020 (mmt carbon equivalent)

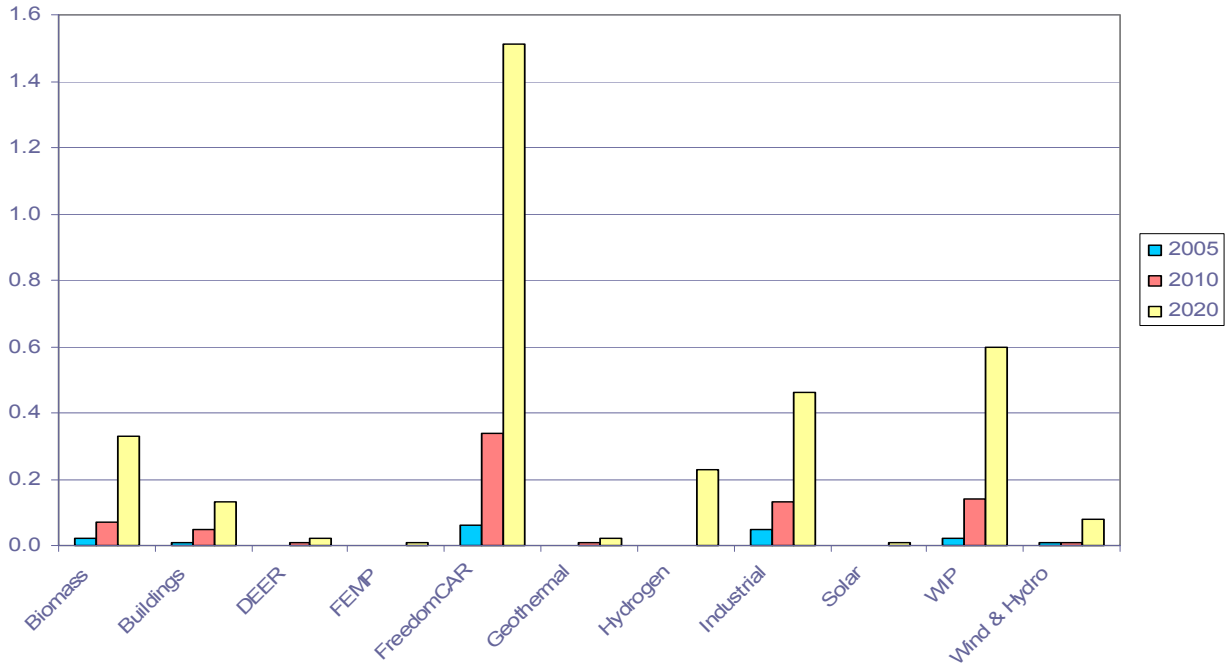

Figure 3.12. Annual Oil Savings: 2005, 2010, 2020 (quadrillion Btu)

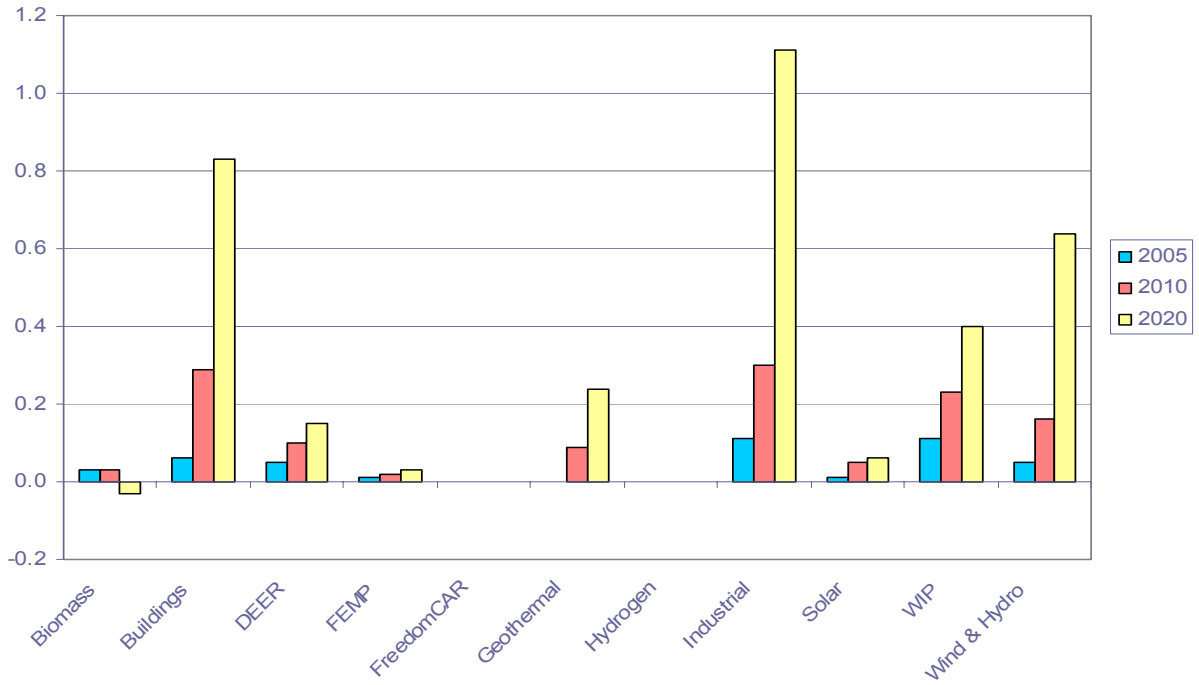

Figure 3.13. Annual Natural Gas Savings: 2005, 2010, 2020 (quadrillion Btu)

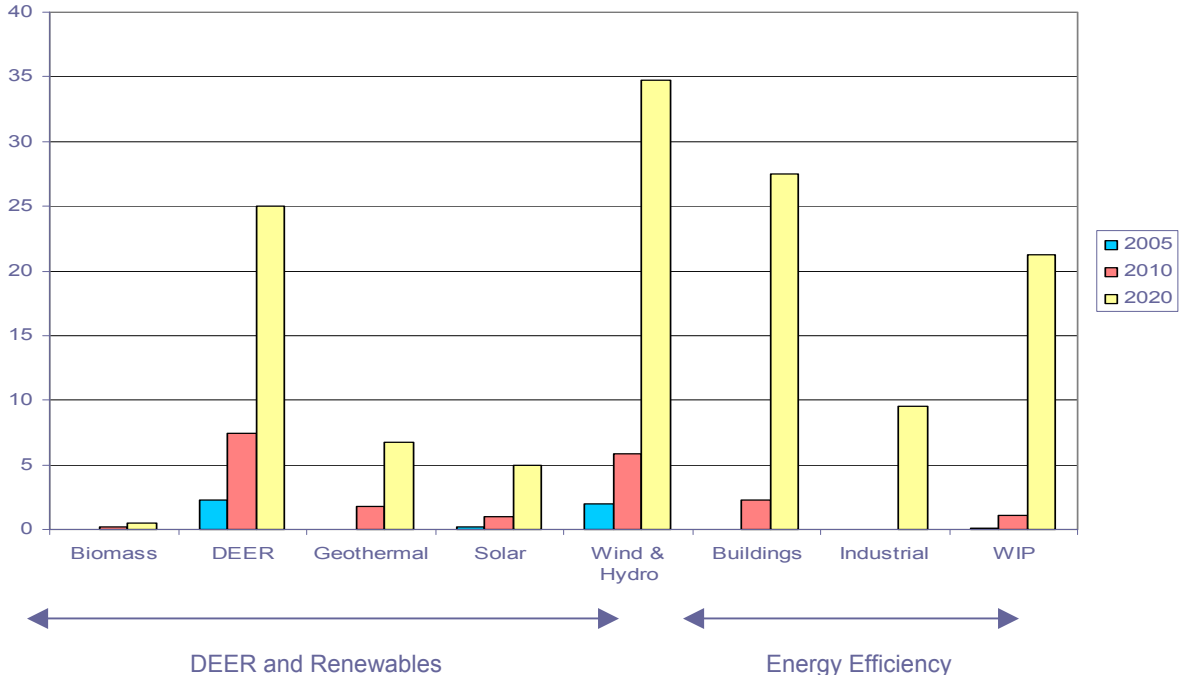

Figure 3.14. Annual Renewable Electric Capacity – Energy Efficiency, DEER, and Renewables: 2005, 2010, 2020 (gigawatts)

Note: The FEMP, Hydrogen, and FCTV programs either do not have renewable electric-capacity impacts or do not have measurable impacts in quads by 2020.

CHAPTER 4

BENEFITS ANALYSIS OF EERE'S PROGRAMS

Introduction

As outlined in the description of Step 2 of the EERE benefits-analysis process in **Chapter 2**, the inputs for estimating benefits for each of EERE's 11 programs are developed using a variety of analytical tools suitable for assessing specific target markets. The results of these analyses are then reflected in NEMS-GPRA04 to estimate the benefits for each program and for EERE's overall portfolio. In some cases, program performance goals (outputs) can be incorporated directly into NEMS-GPRA04. In other cases, adjustments to the program analyses have to be made when incorporating them in NEMS-GPRA04. This chapter describes the NEMS-GPRA04 analyses for each program. It is helpful to recognize the uses and limits of the NEMS-GPRA04 model—the final modeling step for EERE benefits analysis (see **Box 4.1 – Uses and Limitations: NEMS-GPRA04** at the end of the chapter).

To aid the reader, **Table 4.1** shows a breakdown by program of the two types of analytical tool—specialized "off-line" tools and NEMS-GPRA04—employed in its benefits analyses.

Table 4.1. Program Benefits Modeling by Primary Type of Model Used and Subprogram Area

Program	Subprogram	Step 2 Off-Line Tools	NEMS-GPRA04
Biomass	Bio-products	✓	
	Bio-power		✓
	Cellulosic Ethanol	✓	✓
Building Technologies	Technology R&D	✓	✓
	Regulatory Actions		✓
	Market Enhancement	✓	
DEER	DER / CHP		✓
FEMP		✓	
FreedomCAR & Vehicle Technologies	Light-Vehicle Hybrid and Diesel		✓
	Heavy Vehicles	✓	
	Lightweight Materials	✓	
Geothermal			✓
Hydrogen, Fuel Cells, and Infrastructure Technologies	Fuel Cells		✓
	Production	✓	
Industrial Technologies	R&D	✓	
	Deployment	✓	
Solar Energy Technologies	Solar Buildings		✓
	Photovoltaics	✓	✓
Weatherization and Intergovernmental	Weatherization	✓	
	Domestic Intergovernmental	✓	
Wind and Hydropower Technologies	Wind		✓
	Hydropower	✓	

Required off-line analysis can range from simple verification of program goals to an initial calculation of energy savings, depending on the treatment of the target market in NEMS-GPRA04. Specialized off-line tools are used to develop the inputs to NEMS-GPRA04 for each program case. The subprograms listed are groupings of activities within each program that share either technology or market features. They do not represent actual program management categories. As EERE completes its reorganization, some of this Step 2 off-line analysis can be incorporated directly into NEMS-GPRA04, streamlining the effort considerably.

Biomass Program

The Biomass Program focuses on three major areas: bio-products, bio-power, and cellulosic ethanol (**Table 4.2**). The methodology for computing the EERE FY 2004 benefits estimates varied, depending on the biomass area and the relevant components of the NEMS-GPRA04 framework.[1]

Bio-products: The bio-products activities seek to develop biomass-based chemical products through innovative biomass-conversion processes. The use of biomass would displace traditional reliance on petroleum and natural gas as chemical feedstocks. Because of the multitude of products and the complexity of the chemicals industry, NEMS-GPRA04 does not have sufficient detail within its representation of this industry to explicitly model bio-products. Energy savings were estimated by the program that reflected an assumption of 15 percent per year growth from 2010. The energy savings by fuel type (the largest share was petroleum feedstocks) were implemented in the integrated model by subtracting the estimates from industrial energy consumption otherwise projected by NEMS-GPRA04. The model was then used to compute the other benefits of primary energy savings, carbon emission reductions, and energy expenditure savings.

Bio-power: The main thrust of the bio-power activities are to develop and verify gasification technologies that enable the increased efficiency of bio-power generation from the current 20 percent efficiency to 30–35 percent efficiency. In estimating the benefits of EERE's FY 2004 budget request, the biomass generation capital and operating and maintenance (O&M) costs were modified to reflect the program's goals, as reflected in the EERE/EPRI *Renewable Energy Technology Characterizations* report.[2] These costs and the biomass heat rates are very similar to those already in the Baseline Case, although the projected increase in biomass capacity is quite small in the baseline. In addition to competing on an economic basis with other electricity-generation technologies, biomass capacity may be constructed for its environmental benefits. Projections for green power biomass installations, as developed by Princeton Energy Resources International (PERI) using their Green Power Market Model, were incorporated into NEMS-GPRA04 as the planned capacity additions. The majority of projected biomass-generating capacity in this forecast stems from the green power additions. The roughly 500 MW by 2020 is expected to generate 3.7 billion kilowatt-hours.

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[1] The Biomass Program was created from three activities located in three different offices under the old organization. Appendix D provides details of the off-line benefits analysis.

[2] This report can be found on the Web at http://www.eere.energy.gov/power/pdfs/techchar.pdf.

Cellulosic ethanol: Cellulosic ethanol research is aimed at reducing the cost of producing ethanol from cellulosic biomass (corn is currently the U.S. feedstock). The improvements in cellulosic ethanol production costs in the AEO2002 (and, therefore, the EERE Baseline Case) are similar to the program's goals—but the growth in projected production is assumed to be constrained. For the FY 2004 EERE benefits estimates, these constraints are relaxed, so that cellulosic ethanol production equals the program goals (assuming other baseline assumptions), which were developed using EERE's ethanol analytic model. NEMS-GPRA04 then adjusts the overall level of ethanol purchased by accounting for the price impacts of competing sources of demand for biomass (e.g., for electricity production). Petroleum and fossil energy savings occur when the cellulosic ethanol displaces gasoline through enhanced blending. In the FY 2004 EERE benefits projections, a large portion of the cellulosic ethanol displaces corn ethanol, which does not lead to fossil energy savings. The cellulosic ethanol research, however, does lead to additional carbon emission savings through its lower life-cycle carbon emissions. The NEMS-GPRA04 results are adjusted to reflect this differential in net carbon emission during the analysis period.

Table 4.2. FY 2004 Benefits Estimates for Biomass Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.06	0.10	0.33
▪ Cellulosic ethanol production (billion gallons)	0.00	0.11	0.82
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.0	0.6	1.9
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.6	0.8	3.6
Security			
▪ Oil savings (quadrillion Btu)	0.02	0.07	0.33
▪ Natural gas savings (quadrillion Btu)	0.03	0.03	-0.03
▪ Renewable electric-generating capacity* (gigawatts)	0.0	0.2	0.5

* Includes bio-power only.

Building Technologies Program

The activities of the Building Technologies Program can be classified into three general types: technology R&D, regulatory actions, and (to a lesser extent) market enhancement. With the reorganization of EERE, the majority of the market-enhancement activities in buildings markets are part of the Weatherization and Intergovernmental Program.[3]

Technology R&D: The technology R&D activities seek to develop new or improved technologies that are more energy efficient and more cost-effective than the alternatives currently available. The forecast benefits for these are measured by modifying the technology slates that are available in the Baseline Case. Building technologies in NEMS-GPRA04 are represented by end use. For most end uses, there are conversion technologies (e.g. furnaces and water heaters)

[3] Appendix B provides the details of the off-line calculations.

that use different fuels and that have several different levels of energy efficiency. The Baseline Case incorporates EIA's estimation of future technology improvement that is then modified in the Program Case.

Residential shell technologies, such as windows or insulation, are represented by several packages of technologies with different levels of improvements. Each package is characterized by a capital cost, as well as heating and cooling load reductions. The commercial-sector shell measures are represented by window and insulation technologies that can be selected individually. The residential methodology was developed by EIA for the AEO2001, while the commercial methodology was developed by OnLocation for EERE.

The residential and commercial sectors are each represented by several building types[4] within nine census divisions. End-use technology choice is computed for each of these building types and geographic regions, based on the relative economics and estimations of consumer behavior for the technologies. The latter is important to replicate current technology market shares.

Improved EERE technologies that have no incremental costs above the baseline technologies, such as Commercial Buildings Integration R&D, must be treated differently. If they were introduced into the modeling framework as technologies with zero incremental costs, there would be immediate adoption and unrealistic market shares. Thus, for these activities, off-line penetration estimates are used to compute a target savings. The target savings, however, are first reduced by 30 percent, as are other off-line estimates that cannot be modeled on an economic basis.[5] These savings were achieved in NEMS-GPRA04 by lowering the consumer hurdle rates for the appropriate end uses or by modifying the autonomous shell-efficiency indices.

Regulatory activities: Regulatory activities include the setting of new appliance standards, based on the legislatively mandated schedule; and encouraging State adoption of more stringent building codes. Representing appliance standards is straightforward. In the year that the new standard is assumed to be implemented (based on program goals), all technologies that are less efficient than the standard are removed from the market and unavailable for consumer choice. The resulting energy savings depend on the difference in the level of efficiency of the standard compared to the technology that had been selected in the Baseline Case. The baseline was adjusted to remove any future appliance standards in the AEO2002 that are part of the Building Technologies Program. As a result, the revised Baseline Case has higher space-heating consumption in the residential model and space-cooling consumption in the commercial model.

Market enhancement: Building-code development is a regulatory activity at the State level. The Building Technologies Program provides technical assistance in developing new codes and helps States to adopt updated standards. A spreadsheet computation of average savings is made using program estimates for the fraction of buildings within areas that adopt more stringent codes; and the heating, cooling, and lighting load reductions associated with the new levels of codes. The building shell packages are modified to produce the appropriate savings.

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[4] The residential sector is includes three building types and the commercial sector by 11 types (e.g., offices, schools, etc.).
[5] See Chapter 2, Footnote 12.

The Building Technologies Program benefits (**Table 4.3**) are estimated with the integrated NEMS-GPRA04, so that the electricity-related primary energy savings are directly computed. In addition, the estimates include any feedbacks in the buildings or other sectors resulting from changes in energy prices that result from the reduced energy consumption.

Table 4.3. FY 2004 Benefits Estimates for Building Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.08	0.41	1.33
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.5	5.5	16.3
Environmental			
▪ Carbon dioxide emission reductions (million metric tons carbon equivalent)	1.3	6.9	22.7
Security			
▪ Oil savings (quadrillion Btu)	0.01	0.05	0.13
▪ Natural gas savings (quadrillion Btu)	0.06	0.29	0.83
▪ Renewable electric-generating capacity (gigawatts)	0.0	2.3	27.5

Distributed Energy and Electric Reliability Program

The Distributed Energy and Electric Reliability (DEER) Program encompasses many technologies and markets. The benefits were estimated by focusing on a segment of the distributed energy market: gas-fired combined heat and power (CHP) systems within commercial building and industrial applications.[6] Distributed energy resource (DER) applications that are motivated by the need for electric reliability primarily will be systems that produce only electricity and are used in backup mode. EERE currently does not have analytical tools to assess this market. Its absence from the benefits estimates may result in an underestimation of DER capacity; although this is less significant in regard to energy or emissions savings, because these systems typically run for few hours per year and generally have similar or lower efficiencies than larger central station plants.[7] To the extent that the central grid relies on DER for emergency power, avoided central station capacity may be underestimated as well.

Combined heat and power systems produce both useful thermal heat and electricity. Their economics depend on the amount of thermal heat needed at the site, the electricity use at the site, the price of the input fuel, and the value of the electricity. If the end-use customer is making the investment, the electricity value will depend on the customer-avoided purchases at the electricity retail price, and possibly the amount of excess electricity sold off-site at prevailing wholesale electricity prices. Using the average electricity price is a simplification that may overlook the requirement to continue paying some type of flat distribution charge, even though less electricity is purchased from the utility. If a vertically integrated electric utility is making the investment,

[6] Appendix D provides the details of off-line analyses.
[7] The exception is building solar systems, which may be purchased for reliability purposes; but which, because they do not require fuel purchases, are operated during nonpeak or nonemergency periods as well.

the value is from avoided generation, and transmission and distribution (T&D) costs. The distributed systems would be placed strategically in the grid to avoid T&D expansion costs.

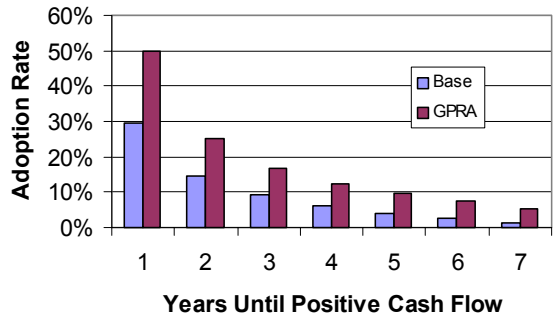
The NEMS-GPRA04 framework uses a cash-flow model to evaluate the DER technologies (CHP and photovoltaic systems) within the building sectors. For commercial buildings, debt and interest payments are computed over a loan period of 20 years, along with associated taxes and tax benefits and assuming a 20 percent down payment. Annual fixed maintenance costs are also included. For the gas-fired CHP technologies, fuel costs are computed based on the delivered cost of natural gas and the technology efficiency. Netted against the fuel cost is the value of the useful waste heat produced as computed, based on the delivered natural gas price, the thermal efficiency of the CHP system, and the internal thermal load. The value of the electricity produced is then subtracted from these costs to determine the cash flow. The value of electricity is equal to the larger of the electricity produced and the internal electricity demand, multiplied by the delivered electricity price. Any electricity produced in excess of internal needs is assumed to be sold to the grid at the wholesale power rate. The number of years until positive cash flow is reached determines the market share in new buildings. The market share (as shown below) drops off sharply as the number of years increases, which reflects the high rates of return generally expected for energy-related projects by commercial building owners. The market share for existing buildings is assumed to be a fraction of the share for new.

The analysis is performed for each of 11 commercial building types in nine regions. Even so, this is a fairly high level of aggregation; and, therefore, the model may not capture some of the niche markets that DER may fill. The DEER Program facilitates the development of the DER market by improving the technology characteristics (lowering costs, improving efficiency, and reducing environmental emissions) and by removing barriers to adoption and consumer acceptance. Thus, the benefits are estimated, based on the impact of improved technology and greater market penetration.

The FY 2004 Baseline Case includes some DER technological advancement.[8] It was beyond the scope and schedule for this year's analysis to separate how much of the baseline improvements might stem from government R&D efforts, and therefore should be removed. As a result, the FY 2004 benefits may be underestimated for the smaller commercial-sector systems. Although not in the AEO2002, the baseline also assumes that small combined heat and power systems receive favorable tax treatment in terms of accelerated depreciation.

The DEER Program's impact on consumer adoption rates was represented in several ways. The maximum market share that can be achieved in new buildings was increased from 30 percent in the Baseline Case to 50 percent in the Program Case. **Figure 4.1** shows how the ultimate market share for new buildings varies by payback year. In addition, there is an adoption-rate parameter that was accelerated to reflect faster market maturity in the Program Case (see **Figure 4.2**).

[8] The Annual Energy Outlook 2002 assumes improved CHP technologies in the commercial sector. The input files for the industrial sector CHP systems show improvements as well, but a coding error led to these being unused and the technology characteristics remain at their year 2000 values.



Source: NEMS-GPRA04 inputs

Figure 4.1. DER Market-Penetration Function in New Buildings for 2010

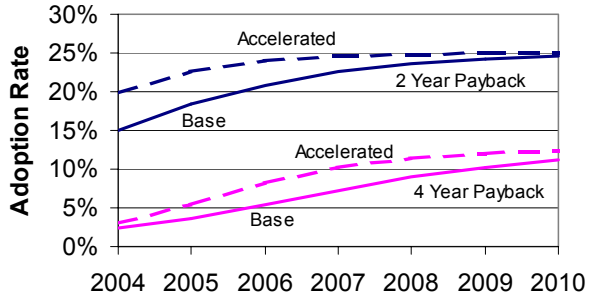
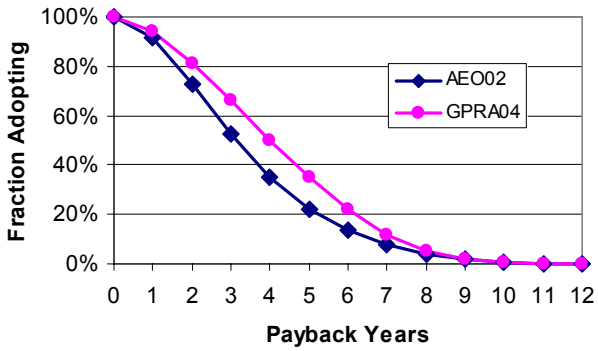


Figure 4.2. DER Market Share Over Time in New Commercial Buildings

The market share for the existing building stock is tied to the market share computed for new buildings. The Baseline Case assumes that the existing stock share is one-fiftieth of the new share, while the Program Case assumes that the existing share is increased gradually from one-fiftieth to one-thirtieth of the new share. The share for the existing stock of buildings is considerably smaller than the market share for new buildings, which reflects that the entire existing stock will not make investments in distributed technologies in a single year.

An economic competition for CHP systems is also performed in the industrial sector. All of the industrial CHP technologies improve over time in the Benefits Case compared to the Baseline Case. The technology characteristics for the smaller internal combustion systems were taken from the draft *EERE Gas-Fired Distributed Generation* and *Microturbine Technology Characteristics* reports, while the larger system improvements are the intended EIA assumptions.[9] For the industrial CHP systems, as well as the commercial sector, it was assumed that the DEER Program will enhance consumer acceptance (see **Figure 4.3**) and lower hurdles to adoption. This was reflected in the model by shifting the function determining the adoption rates as a function of payback years.



Source: NEMS-GPRA04 inputs

Figure 4.3. Industrial CHP Market Acceptance

[9] The assumptions in the AEO2002 input files as described in Footnote 8.

The incremental DER capacity and generation that results from this representation of the DEER Program activities is shown in **Table 4.4**, along with the projected total quantities. Of the 25 GW of incremental capacity, roughly half of the increase is expected from commercial building applications and half from generally larger industrial applications. The DER increase in the building sector is proportionally much larger, because there is currently relatively little DER in this sector.

In the Baseline Case, the commercial sector is projected to satisfy roughly 3 percent of its total electricity demand with distributed generation and 15 percent in the industrial sector. With the DEER Program, the share increases to 8 percent in the commercial sector and 20 percent in the industrial sector.

Table 4.4. Distributed Energy Resources: Capacity and Generation: 2005, 2010, and 2020

	Capacity (GW)			Generation (BkWh)		
	2005	2010	2020	2005	2010	2020
Baseline Case						
Buildings	1.3	2.3	7.4	9	16	53
Industry	29.0	33.0	41.2	173	202	259
Total*	30.3	35.2	48.5	183	218	312
Benefits Case						
Buildings	2.1	5.4	20.3	15	39	146
Industry	30.5	37.3	53.2	184	233	347
Total*	32.6	42.7	73.6	199	272	493
Incremental						
Buildings	0.8	3.2	13.0	6	22	93
Industry	1.5	4.3	12.1	11	31	88
Total*	2.3	7.4	25.0	17	54	180

* Excludes nontraditional large QF cogenerators.

The DEER Program benefits are projected within the integrated modeling framework, so that the impact of the program will be reflected in the remainder of the energy system. As a result of increased investments in DER, electricity purchases from the commercial and industrial sectors are reduced, and additional electricity is sold wholesale to the grid. The central electricity generation industry responds by reducing production from the most expensive plants operating in each region—and, over time, by building fewer central station plants in the face of lower demand. Retirements are relatively unaffected, with only 2 GW of additional capacity retired by 2020 in the Program Case. Roughly 27 GW of central station investments are avoided by the additional DER. In the Baseline Case, about 90 percent of new central station capacity additions from 2005 to 2020 are projected to be natural gas fired, so about 90 percent of those avoided investments are natural gas fired.

Distributed generation makes up roughly 12 percent of new capacity additions from 2005 to 2020 in the Baseline Case. This share increases to 18 percent in the Program Case. For the later period of just 2015 to 2020, the distributed share increases from 16 percent in the Baseline Case to 26 percent in the Program Case.

The energy and carbon emission-reduction benefits that stem from distributed generation are computed as the decrease in traditional central station nonrenewable energy consumption and associated carbon emissions net of the energy and emissions from the DER. The central station generation reductions are from a mix of existing plants and avoided new plants. Over time, the facilities that are used in the Baseline Case become more efficient as the gas combined-cycle and combustion turbine technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour. For example, in 2010, the average nonrenewable energy avoided is at a rate of 9,500 Btu per kWh; and, by 2020, the value is reduced to 7,800 Btu per kWh.

The benefits estimates for the High Temperature Superconductivity (HTS) R&D, another component of the DEER Program, were based on an analysis performed by a contractor for the program. The estimates provided for kilowatt-hour reductions from HTS generators, transformers, cables, and motors were represented in NEMS-GPRA04 by reducing T&D losses. Total benefits for the DEER Program are shown in **Table 4.5.**

Table 4.5. FY 2004 Benefits Estimates for DEER* (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.08	0.19	0.46
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.7	3.1	9.0
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	1.4	3.4	8.5
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.01	0.02
▪ Natural gas savings (quadrillion Btu)	0.05	0.10	0.15
▪ Renewable electric-generating capacity (gigawatts)	2.3	7.4	25.0

* Includes increased market penetration for stationary fuel cells

Federal Energy Management Program

The Federal Energy Management Program (FEMP) is an implementation program to increase the energy efficiency of Federal government buildings, which account for roughly 1.5 percent of residential and commercial building energy consumption. FEMP leads to the installation of a variety of existing technologies, rather than focusing on the development of specific technologies—as do many other EERE programs. Because it encompasses a broad technological scope, while targeting a specific market segment, FEMP is difficult to model in an integrated framework such as NEMS-GPRA04.[10] However, there is also less uncertainty associated with the program, because there is little or no technological risk.

[10] Publicly available documentation of FEMP Program GPRA benefits was not available at the time of this report; however, documentation will be available in the forthcoming GPRA FY2005 Benefits report. The off-line analysis methodology is the same for both years.

Delivered energy savings that have been estimated by FEMP are used as inputs for the integrated modeling. These projected savings are subtracted from the Baseline Case for commercial-building energy consumption. The model is used to compute other benefits metrics of primary energy savings, carbon emission reductions, and energy-expenditure savings (see **Table 4.6**).

Table 4.6. FY 2004 Benefits Estimates for FEMP (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Energy savings (quadrillion Btu)	0.01	0.03	0.07
Economic			
▪ Energy-expenditure savings (Billion 2000 dollars)	0.1	0.4	0.8
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.2	0.6	1.3
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.00	0.01
▪ Natural gas savings (quadrillion Btu)	0.01	0.02	0.03
▪ Renewable electric-generating capacity (gigawatts)	0.0	0.0	0.0

FreedomCAR and Vehicle Technologies Program

The FreedomCAR and Vehicle Technologies (FCVT) Program consists of research on light-vehicle hybrid and diesel technologies, heavy vehicle and parasitic loss reduction technologies, and lightweight materials for engines and vehicles. In addition, the program includes research in advanced petroleum and renewable fuels.[11]

Light-vehicle hybrid and diesel technologies: This research aims to improve engine technologies in light-duty vehicles, which include passenger cars and light-duty trucks. Benefit estimates for these activities are computed by an analysis process, which estimates the penetration (sales) of the various technologies in the market for light-duty vehicles over time. The amount that each technology penetrates into the market determines the stock of these vehicles and the vehicle miles traveled (VMT) associated with each technology. Fuel cell vehicles are included in the modeling with the other transportation vehicles, but their associated savings are attributed to the Hydrogen, Fuel Cells, and Infrastructure Technologies Program. **Appendix E** provides detailed data on light vehicles.[12]

Heavy vehicle and parasitic loss reduction technologies: Heavy vehicles are those that have a gross weight (the weight when fully loaded of 10,000 pounds or more). The benefits of this R&D activity are derived from penetration rates estimated by the Heavy Vehicle Model developed for the FCVT using efficiency and technology cost assumptions. This model, by TA Engineering, Inc., is described in **Appendix E**.

[11] Details of the off-line analysis for light-duty and heavy vehicles are presented in Appendix E.

[12] Several updates were made to the actual values in the table compared to the previous year. Those values can be found in the 2003 GPRA methodology report on the EERE Web site (http://www.ott.doe.gov/facts/pdfs/appendix2003.pdf). No methodology report for 2004 has been written.

Lightweight materials for engines and vehicles: The lightweight materials developed under this program are used in both light and heavy vehicles. The benefit estimates for materials are proportional to the percent of the fuel economy gain in light vehicles that is due to weight reduction. The benefits from weight reduction for heavy vehicles will be estimated in the future, but they are not in the current estimates.

In the NEMS-GPRA04 integrating model, the light-duty vehicle (LDV) market consists of six car classes—mini-compact, subcompact, compact, midsize, large, two-seater—and six light-duty truck classes—small and large pickup, small and large van, small and large sport utility vehicle (SUV)—in nine census divisions. For each vehicle type and class and for each region, a number of LDV technologies compete against each other in the market for vehicle sales. These include conventional gasoline, advanced combustion diesel, gasoline hybrids, diesel hybrids, gasoline fuel cell, hydrogen fuel cell, electric, natural gas, and alcohol. Each vehicle technology is represented by a number of characteristics that can change over the forecast time horizon and that influence the technology's acceptance in the marketplace (its sales). These characteristics include the vehicle cost, the fuel cost per mile (a combination of the fuel price and the vehicle efficiency), the vehicle range, the operating and maintenance cost, the acceleration, the luggage space, the fuel availability, and the make and model availability. The NEMS-GPRA04 model also includes "calibration" coefficients to calibrate the model to historical data. The associated characteristics for all the "nonconventional" technologies are specified as relative to those for the conventional gasoline vehicle.

The model estimates the sales penetration share of each technology in all of the vehicles, classes, and regions in each year of the forecast. The various characteristics of the technologies determine the technology's acceptance in the marketplace, but each characteristic has a differing degree of influence. The vehicle cost is generally the most influential of the characteristics, certainly having a much stronger influence than luggage space, for example. All the technologies are competed against each other using a nested logit formulation. In a logit formulation, the sum of all the influences from the characteristics for each technology is the "utility" for that technology, and the relative sizes of the "utility" for each technology determines the relative penetration shares for that technology. Technologies that have higher "utilities" are given greater sales shares. The overall sales penetration results are the sum of the more disaggregated results.

In the FY 2004 benefits analysis, the Baseline Case for transportation programs is essentially the AEO2002 Reference Case, which already includes some small amount of penetration for the program vehicle technologies. The Program Case uses the program technology characteristics, along with a variety of other assumptions relating to behavioral responses in the underlying logit formulation of the NEMS-GPRA04 model. These include removing the "calibration" coefficients (used by the model for a tie to history) from the formulation and revising the coefficients for make and model availability. These later changes reflect the program's partnerships with manufacturers that make the alternative-fuel vehicles more widely available. The removal of the calibration coefficients that bias the choice to conventional gasoline vehicles represents that consumers become more comfortable with other vehicles types, due to improved attributes and greater adoption rates. In other words, there is a learning-by-doing effect, where the bias is eliminated due to more experience with the new vehicles.

In the FY 2004 benefits results, the overall sales share for gasoline vehicles decreases from 87 percent in 2020 in the Baseline Case to 43 percent in the Program Case. This decrease in share is due to the penetration of the alternative technologies. The overall share in 2020 for advanced combustion diesel increases from 3 percent to 9 percent, for gasoline hybrids from 3 percent to 33 percent, and for diesel hybrids from 1 percent to 3 percent. (See **Figures 4.4 and 4.5**, below.)

These large vehicle sales shares for advanced technology vehicles in 2020, however, translate into much smaller shares for overall vehicle stocks (**Figures 4.6 and 4.7**) and overall shares of vehicle miles traveled (VMT) (**Figures 4.8 and 4.9**) for each technology. The stock shares depend on the share of sales over time, which only gradually increases for the alternative technology vehicles, and the rate of vehicle replacement and growth. The total VMT for gasoline vehicles falls from 3,218 billion miles in 2020 to 2,211 (about 61 percent of the VMT) between the two cases. The total VMT for advanced combustion diesel increases from 94 to 345 (9.5 percent), for diesel hybrids from 24 to 69 (2 percent), and for gasoline hybrids from 84 to 695 (19 percent).

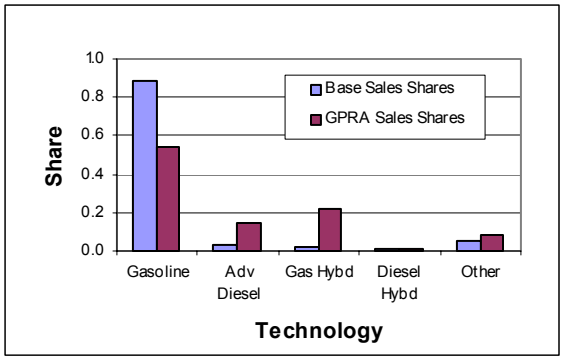


Figure 4.4. Vehicle Sales Shares in 2010

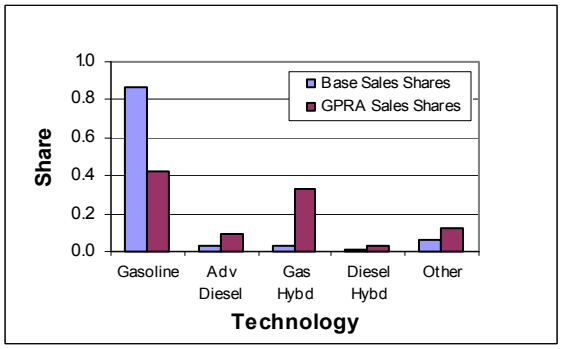
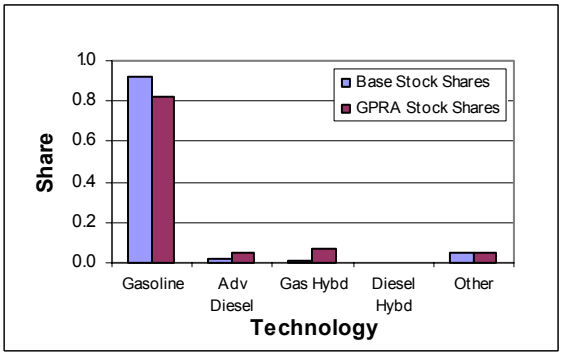


Figure 4.5. Vehicle Sales Shares in 2020



Source: NEMS-GPRA04 outputs

Figure 4.6. Vehicle Stock Shares in 2010

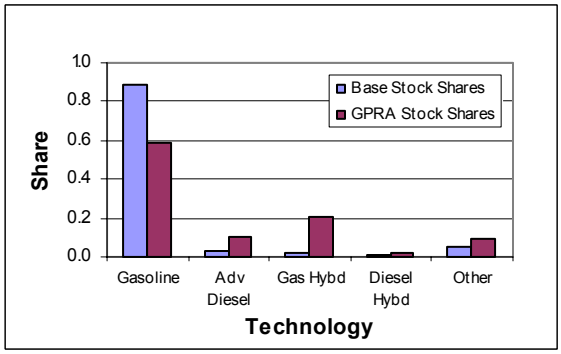


Figure 4.7. Vehicle Stock Shares in 2020

The miles per gallon (MPG) for advanced combustion diesel and for hybrid vehicles is much greater than the MPG for conventional gasoline vehicles. As a consequence, since these advanced-technology vehicles are substituting for the conventional gasoline vehicles, there is a considerable amount of fuel savings. The total estimated amount of fossil energy savings, due to

the advanced-combustion diesel technology, is about 0.13 quadrillion Btu; and, due to the hybrid-vehicle technology, is about 1.00 quadrillion Btu.

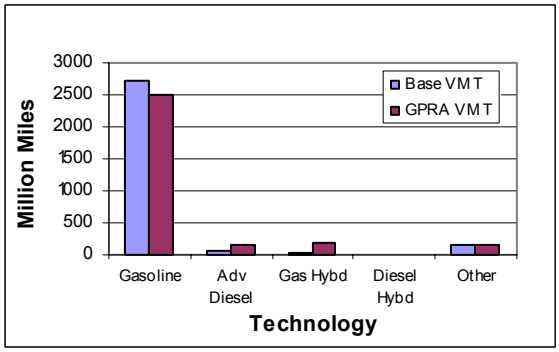
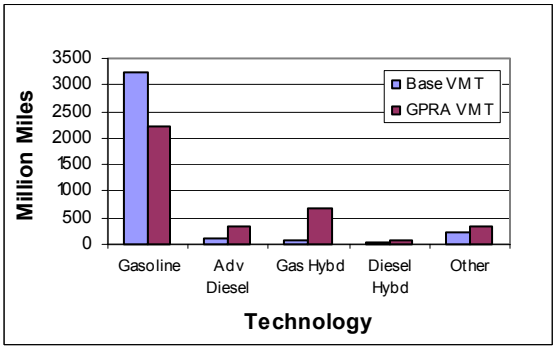


Figure 4.8. Vehicle Miles Traveled in 2010



Source: NEMS-GPRA04 outputs

Figure 4.9. Vehicle Miles Traveled in 2020

In a fully integrated NEMS-GPRA04 model run, the savings are typically somewhat less because of feedback effects that come through integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, reduced gasoline demand causes lower gasoline prices; which, in turn, leads to an increase in travel and less-efficient vehicles purchases than would otherwise have occurred absent the price change. The rebound of gasoline consumption reduces the off-line savings. At the same time, energy-expenditure savings are greater. The small decreases in price apply to the total amount of fuel consumed and contribute significant additional expenditure savings. In addition, the "rebound" effect is also influenced by the fact that vehicles are more efficient, which reduces the cost to drive and causes more miles to be driven. **Table 4.7** presents the total program benefits.

Table 4.7. FY 2004 Benefits Estimates for FreedomCAR and Vehicle Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Energy savings (quadrillion Btu)	0.08	0.32	1.58
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	3.0	9.4	25.5
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	1.3	6.4	29.8
Security			
▪ Oil savings (quadrillion Btu)	0.06	0.34	1.51
▪ Natural gas savings (quadrillion Btu)	0.00	0.00	0.00
▪ Renewable electric-generating capacity (gigawatts)	0.0	0.0	0.0

FreedomCAR and Vehicle Technologies Program Specific Example

Selected vehicle attributes for large cars sold in the South Atlantic Census division for 2020 are illustrated in **Table 4.8**. The technologies other than conventional gasoline are shown as factors relative to conventional gasoline vehicles. The fuel cost of driving is an intermediate variable expressed as cost per mile, which is calculated as the projected cost of the fuel per gallon divided by the miles per gallon. It is the only factor that varies by region, while the others may change by size class. There are other attributes provided by the program (e.g. luggage space, acceleration), which are not shown here, but they have less influence in the choice of a vehicle. In addition, there are a few other behavioral indices and coefficients that are changed to represent the market-enhancement activities of the program and help remove the Baseline Case assumption of a bias against alternative-fuel vehicles.

Table 4.8. Selected Vehicle Attributes (Year 2020, South Atlantic Region, Large Cars)

	Vehicle Cost (2000$)	Fuel Cost of Driving (2000$/mile)	Vehicle Range (miles/tank)	Maintenance Cost (2000$/yr)
Gasoline	33,890	5.18	554.7	1,102
Relative Attributes to Gasoline (e.g., a value of 1.000 below signifies the same value as for gasoline)				
Advanced Diesel	1.050	0.690	1.200	1.000
Ethanol Flex	1.073	1.044	0.730	1.010
CNG Bi-Fuel	1.040	0.909	0.750	0.900
Hybrid-Gasoline	1.010	0.667	1.000	1.000
Hybrid-Diesel	1.150	0.552	1.000	1.050
CNG	1.040	0.697	0.750	0.900
Fuel Cell-Gasoline	1.350	0.555	1.000	1.000
Fuel Cell-Hydrogen	1.250	0.777	0.900	1.050
Electric	1.874	1.171	0.144	0.000

In the nested logit model, each of these attributes for the various technologies has a coefficient or weight associated with it, which determines the relative influence of the attribute. Vehicle cost is one of the most important. This follows intuition as indicated by the following example. For a conventional vehicle that is driven 12,500 miles per year, the annual fuel and operating costs total $1,750 ($648 for fuel, plus $1,102 for maintenance), while the purchase cost is $33,890.

The gasoline-hybrid vehicle, which has a relatively small cost penalty above the conventional vehicle in the Program Case, is the alternative that receives the most market share in 2020 next to conventional. The gasoline-hybrid purchase cost is 1 percent (or $339 greater), but would save $216 per year in fuel costs ($648 * (1-0.667)). The diesel hybrid, on the other hand, costs more than $5,000 more than the conventional vehicle with a fuel savings of $290 annually. The relative attractiveness of the vehicles will vary by size class and, to a lesser extent, by region.

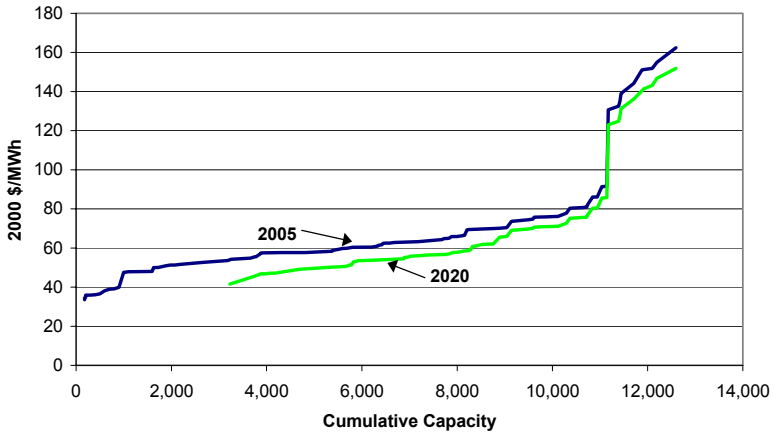
The logit function inherently represents the distribution of consumer preference, and no single vehicle type receives 100 percent of the market share within a size range and region. As shown previously, the gasoline hybrid sales share in 2020 is 33 percent averaged across all regions and size classes, while the diesel hybrid share is only 3 percent.

Geothermal Technologies Program

The primary goal of the Geothermal Technologies Program is to reduce the cost of geothermal-generation technologies, including both conventional and engineered geothermal source (EGS) systems. Measuring the benefits involves projecting the market share for these technologies based on their economic and environmental characteristics.[13]

The NEMS-GPRA04 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (i.e. availability), the regional load requirements, and existing capacity resources. Geothermal capacity is treated in a unique manner, due to the specific geographic nature of the resources. The model characterizes 51 individual sites of known hydrothermal geothermal resources, each with a set of capital and O&M costs. For the Program Case, an additional set of EGS sites were added to this slate.

The Geothermal Program was represented by reducing the capital and O&M costs for all hydrothermal geothermal sites, so that the average of the three lowest-cost sites matched the program's cost goals, as reflected in the EERE/EPRI *Renewable Energy Technology Characterizations* report. Separate program technology goals were provided for the added EGS sites. **Figure 4.10** illustrates the supply curve of the sites in the Northwest in 2005 and 2020 that reflect the cost reductions. The lowest part of the curve is not depicted for 2020 because it represents a portion of the capacity already developed. In addition, the program was assumed to reduce the risk associated with new geothermal development, and the Baseline Case limit on the size of annual developments per geothermal site was increased from 25 MW or 50 MW (depending on year) to 100 MW per year.



Source: NEMS-GPRA04 inputs

Figure 4.10. Geothermal Supply Curve, Northwest Region

In addition to competing on an economic basis with other electricity-generation technologies, geothermal capacity may be constructed for its environmental benefit. PERI, using its Green

[13] See Appendix D for off-line analysis details.

Power Market Model, provided an estimate of geothermal capacity additions in response to the expanding green power markets across the country. The projections for green power geothermal installations were incorporated into NEMS-GPRA04 as planned capacity additions.

The primary energy, oil, and carbon emissions savings stem from geothermal power displacing fossil-fueled generation sources that were built in the Baseline Case. Over time, the new facilities that are constructed in the Baseline Case become more efficient as natural gas combined-cycle and combustion turbine technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour of renewable generation. Geothermal facilities generally have high utilization rates, and the projected incremental 6.7 gigawatts of capacity in 2020 produces 53 billion kilowatt-hours of power. Energy expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. **Table 4.9** shows the overall Geothermal Technologies Program benefits.

Table 4.9. FY 2004 Benefits Estimates for Geothermal Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.00	0.10	0.40
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.0	0.6	1.8
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.1	1.7	7.5
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.01	0.02
▪ Natural gas savings (quadrillion Btu)	0.00	0.09	0.24
▪ Renewable electric-generating capacity (gigawatts)	0.0	1.8	6.7

Hydrogen, Fuel Cells, and Infrastructure Technologies Program

The Hydrogen, Fuel Cells, and Infrastructure Technologies Program is targeted toward the introduction of fuel cells for both stationary and vehicular applications and the production of hydrogen at a reasonable price. The FY 2004 benefits estimates focus on gasoline and hydrogen fuel cells for vehicles. The program has not yet established technology goals for stationary fuel cells, so their benefits could not be computed. As a result, the Hydrogen Program benefits are underestimated. The production side of the program was represented as success in delivering hydrogen at $2 per gallon of gasoline equivalent (inclusive of taxes). As a mid-term model, the NEMS-GPRA04 framework does not contain sufficient structure to analyze the production and delivery of hydrogen.

The fuel cell vehicles were modeled along with the FreedomCAR and Vehicle Technologies Program. The gasoline and hydrogen fuel cell vehicle costs and efficiencies were modified to reflect the program goals (see the FreedomCAR Program description for more detail regarding

the modeling of vehicle choice). In addition, hydrogen availability for vehicle refueling was assumed to be 10 percent by 2018 and 25 percent by 2020. The benefits associated with fuel cell vehicles were attributed to the Hydrogen Program, based on their relative efficiencies and their share of the displaced conventional gasoline vehicles VMT. **Table 4.10** presents the overall benefits.

Table 4.10. FY 2004 Benefits Estimates for Hydrogen, Fuel Cells, and Infrastructure Technologies Program* (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.00	0.00	0.24
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	0.0	0.1	3.9
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.0	0.1	4.6
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.00	0.23
▪ Natural gas savings (quadrillion Btu)	0.00	0.00	0.00
▪ Renewable electric-generating capacity (gigawatts)	0.0	0.0	0.0

* Does not include any benefits from stationary fuel cells.

Industrial Technologies Program

The Industrial Technologies Program consists of hundreds of projects—covering a wide array of industries—with the objective of increasing energy efficiency. These can be characterized in two categories, R&D and deployment. The R&D projects generally apply to specific industries or to specific technologies that are crosscutting across industries. The R&D projects seek to develop new or improved technologies that are more energy efficient and more cost-effective than the alternatives currently available. The deployment projects seek to increase the adoption of existing, as well as new energy-efficient technologies.

Benefit estimates for these projects (see **Table 4.11**) are implemented in NEMS-GPRA04 by increasing the rate of change of technological progress in the industrial sector.[14] The process starts with a baseline rate of change of technological progress and increases it by energy source to approach a target determined by the off-line project estimates. The project target estimates are first reduced by 30 percent, as is done for estimates in other programs that cannot be modeled on an economic basis.

The industrial sector of the NEMS-GPRA04 integrating model consists of 15 industry types in nine census divisions (the detailed modeling is done at a four-census region level). The industries consist of six nonmanufacturing and nine manufacturing. The manufacturing industries are modeled through a detailed process-flow or end-use accounting structure. Each industry consists of three related and interacting modeling components, process/assembly, buildings, and

[14] Appendix C provides details of the off-line analyses.

boiler/steam/cogeneration. The model accounts for 17 main energy sources, including feedstocks and renewables.

The industrial model representation of each energy source for each process step in each industry and in each region begins with a Technology Progress Curve (TPC). The TPCs apply only to the process/assembly component and are designated for both new and existing technologies. This curve relates the amount of energy consumed per unit of output for the process over time and is sensitive to energy prices.

The benefits estimates are calculated in the model by changing the TPCs over time. The off-line energy-saving estimates by fuel type (consisting of electricity, natural gas, petroleum, steam coal, feedstocks, and steam) are used to create target energy-consumption levels. As noted above, the program's target estimates are first reduced by 30 percent. The TPCs in the model for both new and existing technologies in the process/assembly component are adjusted to approximate the target delivered energy use for each of the six energy sources when the industrial model is run alone without energy price feedbacks. The fully integrated NEMS-GPRA04 is then run to compute the benefits metrics of primary energy savings, carbon emission reductions, and energy-expenditure savings that are associated with the fuel consumption reductions.

The resulting estimated primary savings are slightly lower than those targeted because of feedback effects that come through the integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, the lower energy consumption causes lower energy prices (although the feedback is small); which, in turn, feed back to raise energy consumption to be a bit higher than it otherwise would have been—and lead to slightly lower program savings.

Table 4.11. FY 2004 Benefits Estimates for Industrial Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable Energy Savings (quadrillion Btu)	0.18	0.56	2.13
Economic			
▪ Energy Expenditure Savings (billion 2000 dollars)	1.7	4.4	20.2
Environmental			
▪ Carbon Savings (million metric tons carbon equivalent)	3.2	9.9	36.3
Security			
▪ Oil Savings (quadrillion Btu)	0.05	0.13	0.46
▪ Natural Gas Savings (quadrillion Btu)	0.11	0.30	1.11
▪ Displaced Capacity (gigawatts)	0.0	0.0	9.5

Solar Energy Technologies Program

The Solar Energy Technologies Program encompasses several technologies in thermal heat and electric markets.[15] The solar buildings component is focused on developing low-cost solar hot-water and pool heaters to displace fossil-fueled or electric alternatives. For electricity generation, photovoltaics (PVs) are being improved for both distributed and central generation applications. Concentrated solar power R&D also has been part of the Solar Energy Technologies Program, but is not included in the FY 2004 Budget Request. As a result, concentrated solar power has not been included in the GPRA 2004 benefits estimates.

The benefits for solar water and pool heaters are represented within the residential module of NEMS-GPRA04. The solar water heater is a specific technology defined by its capital cost, O&M costs, and electrical use. The baseline assumptions were modified to reflect the program goals of $1,000 per unit and a backup faction of 40 percent. The costs were changed for both new and replacement water heaters. The pool heaters could not be modeled based on economics, because there is not a pool heating end use within NEMS-GPRA04. In addition, it appears that the program is not really aimed at reducing the cost for solar pool heaters, but rather making them more acceptable. Therefore, the penetration rates and energy savings estimated by the program were used to exogenously reduce water-heating demand in the residential model.

Photovoltaic systems are represented using two methods. The capital and O&M costs for utility-scale systems were modified to reflect the program's goals, as reflected in the EERE/EPRI *Renewable Energy Technology Characterizations* report. The regional capacity factors in the Baseline Case already were similar to those in the EERE report, so they were left unchanged. In addition to competing on an economic basis with other electricity-generation technologies, PVs may be constructed for their environmental benefits. PERI, using its Green Power Market Model, provided an estimate of PV capacity additions in response to the expanding green power markets in many places throughout the country. This capacity was incorporated as planned additions in NEMS-GPRA04.[16]

Estimates of primary energy, oil, and carbon emissions savings were based on displacement of energy use for water and pool heating and from electricity demand reductions and PV generation. Because PV systems rely on sunlight, they generally have relatively low capacity factors. Therefore, their energy displacement per unit of capacity is less than that for technologies such as geothermal that are operated primarily as baseload. For example, the roughly 5 GW of incremental capacity in 2020 is projected to generate 9 billion kilowatt-hours in that year. The savings associated with reduced electricity requirements depend on which types of generating plants were built in the Baseline Case. Over time, the new facilities that are constructed in the baseline become more efficient as natural gas combined-cycle and combustion-turbine technologies continue to improve. As a result, the energy and emission savings decline per kilowatt-hour of renewable generation or electricity demand reductions. Energy-expenditure savings are measured as the reduction in consumer expenditures for

[15] Appendix D provides details of the off-line analysis for the Solar Program.

[16] The projections for green power PV installations inadvertently included the Million Solar Roofs Initiative impacts and, thus, overstate the expected capacity. However, the distributed PV technology improvements were not included. The net impact overall is likely to be an understatement of projected PV capacity and program benefits (based on GPRA05 results).

electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. Energy savings from water and pool heaters also directly reduce energy expenditures. Overall benefits of the Solar Energy Technologies Program are shown in **Table 4.12.**

Table 4.12. FY 2004 Benefits Estimates for Solar Energy Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.02	0.07	0.12
Economic			
▪ Energy expenditure savings (billion 2000 dollars)	0.2	0.5	1.4
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	0.3	1.3	2.4
Security			
▪ Oil savings (quadrillion Btu)	0.00	0.00	0.01
▪ Natural gas savings (quadrillion Btu)	0.01	0.05	0.06
▪ Renewable electric-generating capacity (gigawatts)	0.2	1.0	5.0

Weatherization and Intergovernmental Program

The Weatherization and Intergovernmental Program (WIP) encompasses a broad range of activities in virtually all demand sectors of the energy economy. These activities generally are composed of market enhancement, rather than R&D efforts. The major components include International; Native American Renewable Initiative; Weatherization; State and Community Grants; National Industrial Competitiveness through Energy, Environment, and Economics (NICE3); Clean Cities; Inventions and Innovations (I&I); and Gateway Deployment (Energy Star and building codes). The FY 2004 benefits approach varies by activity.[17]

The international activities are currently outside the scope of the integrated modeling framework and are not included in the benefits estimates provided here. The Native American Renewable Initiative also is not being modeled for this year. Weatherization, State and Community grants, and NICE3 are budget-driven efforts—for which benefits are roughly proportional to the size of the budget—that lead to greater adoption of energy efficiency. The Weatherization and State and Community Grants programs are represented by reducing energy consumption in the residential sector based on the program goals. A similar program-specified reduction in energy use is implemented in the industrial sector for the NICE3 program.

The Clean Cities program is represented through improved compressed natural gas (CNG) technology and greater consumer acceptance of CNG vehicles. It is modeled in conjunction with the FreedomCAR and Vehicle Technologies Program, and then the savings from the CNG vehicles are allocated to WIP. The CNG vehicles are used as a proxy for all alternative vehicles that are not part of the FreedomCAR or Hydrogen programs.

[17] Appendix B provides details of the off-line analysis of the Weatherization and Intergovernmental Program (WIP).

The Inventions and Innovation (I&I) program includes many individual grants for different technologies. Those in the industrial sector were treated in the same manner as the NICE3 through exogenous reductions in energy use. The technologies with the largest expected benefits are aluminum-head diesel engines for SUVs, high-efficiency incandescent lightbulbs, high-efficiency air conditioners, and more efficient motors for use in air conditioners. For each of these, a cost and efficiency were estimated with assistance from I&I program contractors. The technologies were then included in the technology slates in the model. The diesel engines were modeled as incremental to the FreedomCAR and Vehicle Technologies Program.

The Energy Star components of the Gateway Deployment component were represented by modifying the consumer behavior coefficients, indicating how consumers trade first-cost expenditures with annual energy savings. The program goals for market penetration were used to determine the degree of change of these parameters. For the compact fluorescent bulb (CFL) activities, the target market share was defined as the fraction of lighting demand rather than the fraction of bulbs, in order to reflect that CFLs are most likely to be installed in high-use fixtures. The other component of Gateway Deployment is a portion of the savings associated with the upgrading of building codes. Because the other portion of the building-code savings are attributed to the Building Technologies Program, the entire code effort was modeled as part of the Building Technologies Program—and then a fraction, based on the off-line estimates was allocated to WIP. Overall benefits for WIP are shown in **Table 4.13.**

Table 4.13. FY 2004 Benefits Estimates for Weatherization and Intergovernmental Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Nonrenewable energy savings (quadrillion Btu)	0.14	0.68	1.42
Economic			
▪ Energy-expenditure savings (billion 2000 dollars)	1.5	6.0	14.7
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent	2.5	8.9	26.3
Security			
▪ Oil savings (quadrillion Btu)	0.02	0.14	0.60
▪ Natural gas savings (quadrillion Btu)	0.11	0.23	0.40
▪ Displaced electric-generating capacity (gigawatts)	0.1	1.1	21.2

Wind and Hydropower Technologies Program

The wind component of the Wind and Hydropower Technologies Program seeks to reduce the cost and improve the performance of wind generation. The FY 2004 benefits (**Table 4.14**) are based primarily on projecting the market share for wind technologies, based on their economic characteristics.

The hydropower program goal is to reduce the environmental impact of hydroelectric facilities. Because this program is driven more by environmental than economic concerns, market

penetration estimates provided by the program analysts for incremental capacity and generation are the primary source for the FY 2004 benefits estimates.

The NEMS-GPRA04 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (i.e. availability), the regional load requirements, and existing capacity resources. Wind is characterized by three wind classes, although the best wind class is assumed to develop first within each region. Other key assumptions that can affect projections include a limit on the share of generation in each region that can be met with intermittent technologies. This was increased from a limit of 12 percent that is used by EIA in the AEO2002, to a limit of 30 percent based on experience in other countries and the program expectations. Another assumption is how quickly the wind industry can expand before costs increase because of manufacturing bottlenecks. This was increased from 50 percent of installed wind capacity to 100 percent. Both of these assumptions were changed for the EERE Baseline Case and the Program Case, although they have no impact on the Baseline Case.

Table 4.14. FY 2004 Benefits Estimates for Wind and Hydropower Technologies Program (NEMS-GPRA04)

Benefits	2005	2010	2020
Energy Displaced			
▪ Non-renewable energy savings (quadrillion Btu)	0.08	0.20	1.15
Economic			
▪ Energy expenditure savings (billion 2000 dollars)	0.6	1.4	5.4
Environmental			
▪ Carbon dioxide emissions reductions (million metric tons carbon equivalent)	1.2	3.2	20.9
Security			
▪ Oil savings (quadrillion Btu)	0.01	0.01	0.08
▪ Natural gas savings (quadrillion Btu)	0.05	0.16	0.64
▪ Renewable electric-generating capacity (gigawatts)	2.0	5.9	34.7

The wind R&D activities were represented by reducing the capital and O&M costs, and by increasing the performance of wind capacity to match the program cost goals, as updated in summer 2001 and modified by the final budget request. In addition to competing on an economic basis with other electricity generation technologies, wind capacity may be constructed for its environmental benefit. PERI, using its Green Power Market Model, provided an estimate of wind capacity additions in response to the expanding green power markets in many places across the country. The projections for green power wind installations were incorporated into NEMS-GPRA04 as planned capacity additions.

The expectation of the hydropower analysts is that future hydroelectric capacity and generation will decrease because of environmental concerns as facilities undergo relicensing. The program goal is to develop hydro turbines that reduce fish mortality rates and, therefore, reduce the risk of these capacity reductions. The AEO2002 projected relatively constant hydropower, implying that the technology was assumed to already be deployed, or that the issue had not been examined. As

a result, the Baseline Case was modified to reflect an estimate of hydro capacity and generation lost in the absence of the fish-friendly turbines. The Program Case then returned hydropower to the prior constant levels, and the forecast benefits result from the increased hydroelectric output.

Estimates of primary energy, oil, and carbon emissions savings result from wind and hydropower displacing fossil-fueled generation sources that were built in the Baseline Case. Over time, the new facilities that are constructed in the baseline become more efficient as natural gas combined-cycle and combustion-turbine technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour of renewable generation. Because wind and hydroelectric systems rely on intermittent resources, they generally have lower capacity factors than geothermal or biomass plants, as can be seen in the capacity factors shown in **Table 4.15**. Therefore, their energy displacement per unit of capacity is smaller. For example, the roughly 35 GW of incremental capacity in 2020 is projected to generate 35 billion kilowatt-hours in that year.

Energy-expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers.

Table 4.15 displays the wind technology assumptions for the Baseline Case and the Program Case. The most significant changes in the Program Case are the increased capacity factors and reduced O&M costs. As described previously, the baseline represents EIA's expectations of technology evolution, which may already include some R&D effects.

Table 4.15. Wind Technology Assumptions

		2005	2010	2015	2020
Baseline					
Average Capital Cost*	2000 $/kW	921	906	867	827
Capacity Factor - Class 6	fraction	0.39	0.42	0.42	0.42
Capacity Factor - Class 5	fraction	0.35	0.38	0.38	0.38
Capacity Factor - Class 4	fraction	0.31	0.34	0.34	0.34
Total O&M Costs	2000 $/kW-year	25.5	25.5	25.5	25.5
Program Case					
Average Capital Cost*	2000 $/kW	954	873	873	849
Capacity Factor - Class 6	fraction	0.44	0.50	0.51	0.54
Capacity Factor - Class 5	fraction	0.39	0.47	0.49	0.51
Capacity Factor - Class 4	fraction	0.31	0.40	0.46	0.47
Total O&M Costs	2000 $/kW-year	14.3	13.9	13.7	13.4

*Includes 1.07 contingency factor

The net result of the improved technology can be expressed in terms of a levelized cost in cents per kilowatt-hour. In the 2010 Program Case, the wind cost is projected to be roughly 3.1 cents per kWh, compared to 4.1 cents per kWh in the Baseline Case. Wind is generally viewed to be a fuel saver, displacing combustion of fossil fuels and related O&M. However, the levelized cost does not reflect the intermittency of wind that may lead to a reduced value in meeting peak

demands, compared to other technologies. In part, its value depends on the consistency and coincidence of wind to electricity demand. In the modeling, wind is only given credit for contributing to a peak demand equivalent to 75 percent of its capacity factor. Each region has a wind profile that indicates expected generation in each season and time of day.

Box 4.1—Uses and Limitations: NEMS-GPRA04

As outlined in Chapter 1, EERE program benefits are estimated using a model of the U.S. energy economy, NEMS-GPRA04. This model is designed to represent the general structure of energy consumption, transformation, and supply. Specific technologies are represented by the fuel, or fuels, they use or the energy services they supply. Parameters within the model represent the characteristics of the technologies, such as efficiency, capital cost, O&M costs, average lifetime, and emissions, all of which are factors that influence the market penetration of the technologies. Research programs are designed to change these technology parameters; e.g., by improving efficiencies or lowering costs. Consumer and business market choices are reflected in the model through a variety of parameters. Many of these parameters reflect the trade-off between initial investment cost and energy costs over time, as expressed in terms of hurdle (discount) rates or through coefficients. In general, end-use consumers are observed to make investment decisions that imply higher hurdle rates than current interest rates. Other considerations in technology choice are also included, such as vehicle attributes pertaining to performance, availability of technologies or fuels, or previous fuel used for replacement appliances. Deployment programs act to reduce many of these barriers to cost-effective technology investments. Yet other EERE activities are aimed at changing the structure of energy markets themselves; e.g., through biorefineries or hydrogen fuels. These latter types of activities are more challenging as they require changes to the structure of the models as well.

By definition, models are simplified, mathematical representations of physical, economic, and social processes. When using a model or the results of a model, one must take into consideration the underlying assumptions of the model, the necessary simplifications that were made in constructing the model, and the intended purpose and objective of the model. Although models can be constructed for a wide range of processes, the remarks in this section deal with energy forecasting models of the type used by EERE in estimating prospective benefits.

One major misapplication in using the results of models is to regard them as predictions of the future. Because models are simplifications of the energy-economic system, they must necessarily omit certain features of energy markets, and thus they are not exact mathematical representations of the energy system. Indeed, many of the mathematical constructs in the models are derived from available data and are intended to estimate the average reaction of one part of the energy system to a change in another part of the system. In addition, behavioral characteristics are indicative of real-world tendencies rather than representations of specific outcomes. Examples of such relationships might be a reduction in passenger vehicle miles driven in response to an increase in gasoline prices, or an increase in domestic natural gas production when the market price of natural gas increases. These relationships are estimated from data to the extent possible, but they are not precisely scientific and therefore cannot be construed as exact predictors.

Energy markets also can be influenced by a number of seemingly random events that cannot be predicted. Examples of such events—or uncertainties—include severe weather, labor strikes, international disruptions, major equipment failures, and regulatory or institutional changes. These types of discontinuities are not well addressed by equilibrium models. Integrating models do assess potential ways in which, disruptions aside, markets might evolve, given assumed policies and external factors such as population growth. While the potential impacts of some future uncertainties can be explored through the use of scenario analysis that vary these assumptions, the timing and magnitude of assumptions must be made through conjecture.

When model results are used, the underlying assumptions are critically important to understanding and interpreting the output. Key assumptions for energy models can include future population growth, economic growth, fossil fuel resources, energy legislation and regulation, and improvements in energy-consuming and energy-producing technologies. Another critical assumption concerns consumer behavior. Some models may assume that consumer behavior remains as indicated by past data; others may assume shifts in behavior. All these assumptions can be important for understanding model outputs. As an example, a model with rapid improvements in and adoption of energy-efficient technologies is likely to have slower growth in energy consumption than another model that assumes slower improvement and/or penetration of the technologies. Therefore, the use of model results should be accompanied by some understanding of the major assumptions.

Box 4.1—Uses and Limitations: NEMS-GPRA04 (continued)

All energy models are simplifications of energy markets; however, they vary widely in the level of detail they incorporate. Some energy models, NEMS-GPRA04 among them, explicitly represent a detailed slate of energy-using technologies, including their capital costs, operating costs, efficiencies, and other technology characteristics, such as likely improvement in the technologies in the future. From those characteristics, the adoption and penetration of technologies are projected, based on algorithms that represent consumer response based on the capital, O&M, and fuel costs of competing technologies, technology efficiencies, discount rates, equipment replacement rates, and a variety of other consumer preference factors. In contrast, some energy models represent future technology and efficiency improvement by a relatively simple assumption about the annual rate of improvement of either energy efficiency or energy efficiency per unit of economic output. Even within models, there are differences in the representation of technologies among sectors. For example, NEMS represents technological improvement in the industrial demand sector and in the oil and natural gas production sector by using annual rates of improvement, because of the difficulty of representing individual technologies directly.

Other levels of detail that may vary between models include geographic disaggregation; time segmentation; institutional, regulatory, and infrastructure representation; customer classes; and consumer responses to different cost and performance factors, among others. Although more detail may improve the representation of energy markets, the availability of credible data to support the detail may be a limiting factor, and a highly detailed model may be more difficult to understand and validate. Also, with the degree of uncertainty in the various data and parameters, some of the finely detailed parameters included in a model may be overwhelmed and made largely irrelevant by uncertainties in the most important parameters influencing the results.

NEMS-GPRA04 represents U.S. energy markets at the regional level and incorporates detail on the structure of energy markets, including Federal and State regulations and legislation, energy infrastructure (such as natural gas pipelines), and other characteristics, such as inventory and stock turnover for energy equipment and structures. In addition, NEMS-GPRA04 represents detailed information about consumer preferences in many end-use sectors. As such, NEMS-GPRA04 is designed to respond to detailed questions on the potential impacts of legislative proposals and other institutional and economic changes. However, given its level of detail, NEMS-GPRA04 is limited in its time horizon to a period of approximately 20 years because projecting regional demographic changes, the regulatory structure of energy markets, and technology characteristics and other factors becomes more difficult and more uncertain further into the future.

Report appendices

The appendices for "Projected Benefits of Federal Efficiency and Renewable Energy Programs - FY 2004 Budget Request" are accessible at http://www.nrel.gov/docs/fy04osti/36404.pdf

Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs

FY 2004 Budget Request

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

(Appendix A Only)

Prepared by the

National Renewable Energy Laboratory

April 2004 NREL/TP-620-36404

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Appendix A – Data: Baseline and Portfolio Cases

EERE Baseline Case

Table 1. Energy Consumption by Sector and Source
(Quadrillion Btu per Year, Unless Otherwise Noted)

	2005	2010	2015	2020
Energy Consumption				
Residential				
Distillate Fuel	0.85	0.79	0.75	0.72
Kerosene	0.08	0.07	0.07	0.07
Liquefied Petroleum Gas	0.44	0.45	0.43	0.41
Petroleum Subtotal	1.37	1.31	1.25	1.20
Natural Gas	5.54	5.70	5.94	6.18
Coal	0.05	0.05	0.05	0.05
Renewable Energy 1/	0.43	0.43	0.44	0.45
Electricity	4.54	4.76	5.09	5.44
Delivered Energy	11.92	12.25	12.76	13.31
Electricity Related Losses...	9.53	9.51	9.85	10.22
Total	21.46	21.77	22.61	23.53
Commercial				
Distillate Fuel	0.42	0.42	0.42	0.42
Residual Fuel	0.12	0.12	0.13	0.13
Kerosene	0.03	0.03	0.03	0.03
Liquefied Petroleum Gas	0.08	0.09	0.09	0.10
Motor Gasoline 2/	0.03	0.03	0.03	0.03
Petroleum Subtotal	0.67	0.69	0.70	0.71
Natural Gas	3.78	4.08	4.43	4.82
Coal	0.07	0.07	0.07	0.08
Renewable Energy 3/	0.08	0.08	0.08	0.08
Electricity	4.45	4.99	5.53	6.01
Delivered Energy	9.04	9.90	10.81	11.69
Electricity Related Losses...	9.33	9.97	10.70	11.30
Total	18.37	19.87	21.51	22.99
Industrial 4/				
Distillate Fuel	1.17	1.22	1.29	1.38
Liquefied Petroleum Gas	2.50	2.66	2.85	3.00
Petrochemical Feedstocks	1.36	1.45	1.54	1.59
Residual Fuel	0.18	0.23	0.25	0.27
Motor Gasoline 2/	0.23	0.24	0.26	0.27
Other Petroleum 5/	4.36	4.77	4.99	5.17
Petroleum Subtotal	9.80	10.57	11.18	11.69
Natural Gas 6/	10.42	11.19	11.79	12.19
Metallurgical Coal	0.69	0.64	0.59	0.54
Steam Coal	1.72	1.74	1.79	1.86
Net Coal Coke Imports	0.07	0.11	0.14	0.16
Coal Subtotal	2.48	2.50	2.52	2.55
Renewable Energy 7/	2.66	2.89	3.18	3.43
Electricity	3.80	4.19	4.53	4.82
Delivered Energy	29.17	31.34	33.20	34.69
Electricity Related Losses...	7.97	8.39	8.77	9.07
Total	37.13	39.73	41.97	43.76

1/ Includes wood used for residential heating.
2/ Includes ethanol (blends of 10 percent or less) and ethers blended into gasoline.
3/ Includes commercial sector electricity cogenerated by using wood and wood waste, landfill gas, municipal solid waste, and other biomass.
4/ Fuel consumption includes consumption for cogeneration.
5/ Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products.
6/ Includes lease and plant fuel and consumption by cogenerators; excludes consumption by nonutility generators.
7/ Includes consumption of energy from hydroelectric, wood and wood waste, municipal solid waste, and other biomass; includes cogeneration, both for sale to the grid and for own use.

	2005	2010	2015	2020
Transportation				
Distillate Fuel	6.35	7.27	8.09	8.71
Jet Fuel 8/	3.88	4.46	5.12	5.82
Motor Gasoline 2/	17.68	19.36	20.92	22.20
Residual Fuel	1.07	1.08	1.09	1.10
Liquefied Petroleum Gas	0.02	0.02	0.02	0.03
Other Petroleum 9/	0.25	0.26	0.28	0.29
Petroleum Subtotal	29.23	32.44	35.52	38.16
Pipeline Fuel Natural Gas	0.79	0.86	0.95	1.02
Compressed Natural Gas	0.06	0.09	0.12	0.14
Renewable Energy (E85) 10/...	0.02	0.03	0.03	0.04
Liquid Hydrogen	0.00	0.00	0.00	0.00
Electricity	0.07	0.08	0.09	0.11
Delivered Energy	30.18	33.50	36.72	39.47
Electricity Related Losses...	0.15	0.16	0.18	0.20
Total	30.32	33.66	36.90	39.68
Electric Generators 13/				
Distillate Fuel	0.06	0.05	0.05	0.07
Residual Fuel	0.23	0.14	0.19	0.21
Petroleum Subtotal	0.30	0.19	0.24	0.28
Natural Gas	5.45	6.78	8.83	10.21
Steam Coal	21.34	22.54	23.17	24.09
Nuclear Power	8.10	7.87	7.49	7.44
Renewable Energy 14/	4.12	4.29	4.54	4.72
Electricity Imports	0.52	0.38	0.45	0.44
Total	39.82	42.05	44.73	47.17
Total Energy Consumption				
Distillate Fuel	8.84	9.74	10.60	11.30
Kerosene	0.13	0.13	0.12	0.12
Jet Fuel 8/	3.88	4.46	5.12	5.82
Liquefied Petroleum Gas	3.04	3.22	3.39	3.54
Motor Gasoline 2/	17.94	19.62	21.20	22.50
Petrochemical Feedstocks	1.36	1.45	1.54	1.59
Residual Fuel	1.60	1.58	1.66	1.72
Other Petroleum 12/	4.59	5.01	5.25	5.44
Petroleum Subtotal	41.37	45.21	48.88	52.04
Natural Gas	26.04	28.69	32.07	34.55
Metallurgical Coal	0.69	0.64	0.59	0.54
Steam Coal	23.17	24.40	25.08	26.07
Net Coal Coke Imports	0.07	0.11	0.14	0.16
Coal Subtotal	23.93	25.16	25.81	26.77
Nuclear Power	8.10	7.87	7.49	7.44
Renewable Energy 15/	7.31	7.72	8.28	8.71
Liquid Hydrogen	0.00	0.00	0.00	0.00
Electricity Imports	0.52	0.38	0.45	0.44
Total	107.28	115.03	122.99	129.95

8/ Includes only kerosene type.
9/ Includes aviation gas and lubricants.
10/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
11/ M85 is 85 percent methanol and 15 percent motor gasoline.
12/ Includes unfinished oils, natural gasoline, motor gasoline blending compounds, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum coke, and miscellaneous petroleum products.
13/ Includes consumption of energy by all electric power generators for grid-connected power except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
14/ Includes conventional hydroelectric, geothermal, wood and wood waste, municipal solid waste, other biomass, petroleum coke, wind, photovoltaic and solar thermal sources. Excludes cogeneration. Excludes net electricity imports.
17/ Includes hydroelectric, geothermal, wood and wood waste, municipal solid waste, other biomass, wind, photovoltaic and solar thermal sources. Includes ethanol components of E85; excludes ethanol blends (10 percent or less) in motor gasoline. Excludes net electricity imports and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal hot water heaters.

Table 2. Energy Prices by Sector and Source
(2000 Dollars per Million Btu, Unless Otherwise Noted)

	2005	2010	2015	2020
Residential	13.26	13.41	13.54	13.91
Primary Energy 1/	7.30	7.24	7.37	7.49
Petroleum Products 2/	9.45	9.85	10.30	10.42
Distillate Fuel	7.68	7.94	8.43	8.55
Liquefied Petroleum Gas..	12.90	13.26	13.64	13.80
Natural Gas	6.81	6.70	6.81	6.96
Electricity	22.40	22.56	22.31	22.70
Commercial	12.83	12.78	12.97	13.31
Primary Energy 1/	5.58	5.55	5.74	5.92
Petroleum Products 2/	6.10	6.36	6.77	6.92
Distillate Fuel	5.44	5.73	6.25	6.40
Residual Fuel	3.74	3.83	3.92	4.02
Natural Gas 3/	5.55	5.48	5.64	5.84
Electricity	20.19	19.80	19.78	20.21
Industrial 4/	5.71	5.97	6.27	6.48
Primary Energy	4.48	4.75	5.04	5.19
Petroleum Products 2/	6.36	6.70	7.08	7.13
Distillate Fuel	5.54	5.89	6.52	6.72
Liquefied Petroleum Gas..	8.28	8.60	8.99	9.11
Residual Fuel	3.57	3.65	3.74	3.87
Natural Gas 5/	3.26	3.44	3.66	3.90
Metallurgical Coal	1.60	1.56	1.52	1.46
Steam Coal	1.35	1.29	1.26	1.21
Electricity	12.67	12.56	12.66	13.05
Transportation	9.59	9.98	10.03	9.99
Primary Energy	9.58	9.96	10.01	9.97
Petroleum Products 2/	9.58	9.96	10.01	9.97
Distillate Fuel 6/	9.23	10.14	10.09	9.97
Jet Fuel 7/	5.53	5.87	6.32	6.37
Motor Gasoline 8/	11.04	11.27	11.28	11.29
Residual Fuel	3.40	3.48	3.57	3.67
Liquefied Petroleum Gas9/	14.09	14.39	14.66	14.62
Natural Gas 10/	6.58	6.83	7.06	7.23
Ethanol (E85) 11/	19.20	20.58	21.07	21.19
Electricity	16.68	18.37	19.42	18.04

1/ Weighted average price includes fuels below as well as coal.
2/ This quantity is the weighted average for all petroleum products, not just those listed below.
3/ Excludes independent power producers.
4/ Includes cogenerators.
5/ Excludes uses for lease and plant fuel.
6/ Low sulfur diesel fuel. Price includes Federal and State taxes while excluding county and local taxes.
7/ Kerosene-type jet fuel. Price includes Federal and State taxes while excluding county and local taxes.
8/ Sales weighted-average price for all grades. Includes Federal and State taxes and excludes county and local taxes.
9/ Includes Federal and State taxes while excluding county and local taxes.
10/ Compressed natural gas used as a vehicle fuel. Price includes estimated motor vehicle fuel taxes.
11/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).

Table 2. Energy Prices by Sector and Source (cont.)
(2000 Dollars per Million Btu, Unless Otherwise Noted)

	2005	2010	2015	2020
Electric Generators 13/				
Fossil Fuel Average	1.57	1.60	1.75	1.85
Petroleum Products	3.82	3.99	4.13	4.27
Distillate Fuel	4.93	5.23	5.72	5.86
Residual Fuel	3.52	3.59	3.67	3.78
Natural Gas	3.16	3.34	3.62	3.86
Steam Coal	1.13	1.05	1.02	0.97
Average Price to All Users 14/				
Petroleum Products 2/	8.79	9.20	9.35	9.35
Distillate Fuel	8.38	9.22	9.36	9.33
Jet Fuel	5.53	5.87	6.32	6.37
Liquefied Petroleum Gas	9.04	9.35	9.68	9.76
Motor Gasoline 8/	11.04	11.27	11.28	11.29
Residual Fuel	3.46	3.54	3.64	3.74
Natural Gas	4.43	4.45	4.59	4.79
Coal	1.15	1.07	1.04	0.99
Ethanol (E85) 11/	19.20	20.58	21.07	21.19
Electricity	18.73	18.56	18.50	18.91
Non-Renewable Energy Expend. by Sector (billion 2000 dollars)				
Residential	152.47	158.48	166.83	178.97
Commercial	114.93	125.57	139.21	154.63
Industrial	123.62	135.95	150.35	162.48
Transportation	281.54	325.22	358.20	383.42
Total Non-Renewable Expend...	672.56	745.21	814.59	879.50
Trans. Renew. Expenditures...	0.40	0.58	0.73	0.84
Total Expenditures	672.96	745.79	815.32	880.34

2/ This quantity is the weighted average for all petroleum products, not just those listed below.
8/ Sales weighted-average price for all grades. Includes Federal and State taxes and excludes county and local taxes.
11/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
13/ Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
14/ Weighted averages of end-use fuel prices are derived from the prices shown in each sector and the corresponding sectoral consumption.

Table 3. Renewable Energy Generating Capability and Generation
(Gigawatts, Unless Otherwise Noted)

	2005	2010	2015	2020
Elect.Generators (excl.cogen) 1/				
Net Summer Capability				
Conventional Hydropower	79.13	78.55	78.46	78.36
Geothermal 2/	3.05	3.46	4.41	5.09
Municipal Solid Waste 3/	3.50	3.83	4.08	4.26
Wood and Other Biomass 4/	1.61	1.73	1.78	1.91
Solar Thermal	0.34	0.36	0.39	0.41
Solar Photovoltaic	0.05	0.11	0.19	0.27
Wind	6.82	7.70	8.40	8.81
Total	95.16	97.08	99.15	100.65
Generation (billion kwh)				
Conventional Hydropower	295.49	288.76	286.99	285.87
Geothermal 2/	15.67	19.25	27.10	32.88
Municipal Solid Waste 3/	24.90	27.41	29.22	30.60
Wood and Other Biomass 4/	14.56	20.23	17.92	14.60
Dedicated Plants	8.93	9.72	10.02	10.85
Cofiring	5.63	10.51	7.90	3.75
Solar Thermal	0.90	0.96	1.05	1.12
Solar Photovoltaic	0.11	0.26	0.46	0.68
Wind	16.74	19.62	21.74	23.21
Total	368.37	376.49	384.48	388.96
Cogenerators 5/				
Net Summer Capability				
Municipal Solid Waste	0.51	0.51	0.51	0.51
Biomass	5.92	6.64	7.62	8.43
Total	6.43	7.15	8.13	8.94
Generation (billion kwh)				
Municipal Solid Waste	3.29	3.29	3.29	3.29
Biomass	33.73	38.05	44.05	48.99
Total	37.02	41.34	47.34	52.29
Other End-Use Generators 6/				
Net Summer Capability				
Conventional Hydropower 7/...	0.98	0.98	0.98	0.98
Geothermal	0.00	0.00	0.00	0.00
Solar Photovoltaic	0.08	0.08	0.08	0.08
Total	1.06	1.06	1.06	1.06
Generation (billion kwh)				
Conventional Hydropower 7/...	4.26	4.17	4.15	4.13
Geothermal	0.00	0.00	0.00	0.00
Solar Photovoltaic	0.18	0.18	0.18	0.18
Total	4.44	4.34	4.32	4.31

1/ Includes grid-connected utilities and nonutilities other than cogenerators. These nonutility facilities include small power producers and exempt wholesale generators.
2/ Includes hydrothermal resources only (hot water and steam).
3/ Includes landfill gas.
4/ Includes projections for energy crops after 2010.
5/ Cogenerators produce electricity and other useful thermal energy.
6/ Includes small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid. Excludes off-grid photovoltaics and other generators not connected to the distribution or transmission systems.
7/ Represents own-use industrial hydroelectric power.

Table 4. Carbon Dioxide Emissions by Sector and Source
(Million Metric Tons Carbon Equivalent, Unless Otherwise Noted)

	2005	2010	2015	2020
Residential				
Petroleum	25.9	24.6	23.4	22.6
Natural Gas	79.7	82.1	85.5	89.0
Coal	1.2	1.3	1.3	1.3
Electricity	222.9	230.5	242.6	255.9
Total	329.7	338.6	352.8	368.7
Commercial				
Petroleum	13.2	13.5	13.8	14.0
Natural Gas	54.4	58.7	63.9	69.4
Coal	1.7	1.8	1.9	2.0
Electricity	218.2	241.7	263.5	282.9
Total	287.5	315.7	343.0	368.2
Industrial 1/				
Petroleum	98.6	107.2	112.8	117.8
Natural Gas 2/	147.6	158.5	167.0	172.5
Coal	63.0	63.3	63.8	64.7
Electricity	186.4	203.3	215.9	227.1
Total	495.6	532.3	559.5	582.1
Transportation				
Petroleum 3/	560.2	622.1	681.0	731.6
Natural Gas 4/	12.2	13.6	15.4	16.7
Other 5/	0.1	0.1	0.1	0.1
Electricity	3.4	3.8	4.4	5.1
Total 3/	575.9	639.7	700.9	753.5
Total by Delivered Fuel				
Petroleum 3/	697.9	767.5	831.0	885.9
Natural Gas	294.0	313.0	331.8	347.5
Coal	65.9	66.4	67.0	68.0
Other 5/	0.1	0.1	0.1	0.1
Electricity	630.9	679.3	726.4	771.1
Total 3/	1688.7	1826.3	1956.2	2072.6
Electric Generators 6/				
Petroleum	6.2	4.0	5.1	5.8
Natural Gas	78.5	97.6	127.2	147.0
Coal	546.2	577.7	594.1	618.3
Total	630.9	679.3	726.4	771.1
Total by Primary Fuel 7/				
Petroleum 3/	704.1	771.4	836.1	891.7
Natural Gas	372.4	410.6	459.0	494.5
Coal	612.1	644.1	661.1	686.3
Other 5/	0.1	0.1	0.1	0.1
Total 3/	1688.7	1826.3	1956.2	2072.6

1/ Includes consumption by cogenerators.
2/ Includes lease and plant fuel.
3/ This includes international bunker fuel which, by convention are excluded from the international accounting of carbon dioxide emissions.
4/ Includes pipeline fuel natural gas and compressed natural gas used as vehicle fuel.
5/ Includes methanol and liquid hydrogen.
6/ Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators. Does not include emissions from the nonbiogenic component of municipal solid waste because under international guidelines these are accounted for as waste not energy.
7/ Emissions from electric power generators are distributed to the primary fuels.

EERE Portfolio Case

Table 1. Energy Consumption by Sector and Source
(Quadrillion Btu per Year, Unless Otherwise Noted)

	2005	2010	2015	2020
Energy Consumption				
Residential				
Distillate Fuel	0.85	0.77	0.71	0.67
Kerosene	0.08	0.07	0.07	0.06
Liquefied Petroleum Gas	0.44	0.44	0.41	0.38
Petroleum Subtotal	1.37	1.28	1.19	1.12
Natural Gas	5.52	5.63	5.73	5.88
Coal	0.05	0.05	0.05	0.05
Renewable Energy 1/	0.43	0.43	0.43	0.43
Electricity	4.48	4.56	4.78	5.05
Delivered Energy	11.84	11.95	12.19	12.52
Electricity Related Losses...	9.40	9.30	9.66	10.10
Total	21.25	21.25	21.85	22.62
Commercial				
Distillate Fuel	0.41	0.40	0.38	0.37
Residual Fuel	0.12	0.12	0.13	0.13
Kerosene	0.03	0.03	0.03	0.03
Liquefied Petroleum Gas	0.08	0.09	0.09	0.10
Motor Gasoline 2/	0.03	0.03	0.03	0.03
Petroleum Subtotal	0.67	0.67	0.66	0.67
Natural Gas	3.82	4.21	4.67	5.28
Coal	0.07	0.07	0.07	0.08
Renewable Energy 3/	0.08	0.08	0.08	0.08
Electricity	4.43	4.87	5.26	5.58
Delivered Energy	9.06	9.89	10.75	11.68
Electricity Related Losses...	9.29	9.92	10.63	11.17
Total	18.35	19.81	21.37	22.84
Industrial 4/				
Distillate Fuel	1.14	1.14	1.11	1.05
Liquefied Petroleum Gas	2.49	2.61	2.76	2.83
Petrochemical Feedstocks	1.34	1.38	1.39	1.29
Residual Fuel	0.18	0.23	0.24	0.22
Motor Gasoline 2/	0.23	0.24	0.26	0.28
Other Petroleum 5/	4.35	4.76	4.96	5.16
Petroleum Subtotal	9.74	10.37	10.72	10.84
Natural Gas 6/	10.40	11.05	11.25	11.41
Metallurgical Coal	0.69	0.65	0.60	0.56
Steam Coal	1.72	1.74	1.77	1.78
Net Coal Coke Imports	0.08	0.11	0.14	0.16
Coal Subtotal	2.49	2.50	2.51	2.50
Renewable Energy 7/	2.66	2.89	3.18	3.43
Electricity	3.73	4.02	4.17	4.27
Delivered Energy	29.01	30.83	31.84	32.45
Electricity Related Losses...	7.83	8.19	8.44	8.55
Total	36.84	39.02	40.27	41.00

1/ Includes wood used for residential heating.
2/ Includes ethanol (blends of 10 percent or less) and ethers blended into gasoline.
3/ Includes commercial sector electricity cogenerated by using wood and wood waste, landfill gas, municipal solid waste, and other biomass.
4/ Fuel consumption includes consumption for cogeneration.
5/ Includes petroleum coke, asphalt, road oil, lubricants, still gas, and miscellaneous petroleum products.
6/ Includes lease and plant fuel and consumption by cogenerators; excludes consumption by nonutility generators.
7/ Includes consumption of energy from hydroelectric, wood and wood waste, municipal solid waste, and other biomass; includes cogeneration, both for sale to the grid and for own use.

	2005	2010	2015	2020
Transportation				
Distillate Fuel	6.38	7.62	8.92	9.68
Jet Fuel 8/	3.88	4.46	5.12	5.82
Motor Gasoline 2/	17.60	18.63	18.94	19.07
Residual Fuel	1.07	1.08	1.09	1.10
Liquefied Petroleum Gas	0.01	0.01	0.01	0.01
Other Petroleum 9/	0.25	0.26	0.28	0.29
Petroleum Subtotal	29.18	32.06	34.36	35.98
Pipeline Fuel Natural Gas	0.78	0.82	0.87	0.92
Compressed Natural Gas	0.05	0.14	0.24	0.33
Renewable Energy (E85) 10/...	0.02	0.03	0.03	0.03
Liquid Hydrogen	0.00	0.00	0.01	0.02
Electricity	0.07	0.08	0.09	0.09
Delivered Energy	30.09	33.13	35.61	37.38
Electricity Related Losses...	0.15	0.16	0.18	0.19
Total	30.24	33.30	35.78	37.57
Electric Generators 13/				
Distillate Fuel	0.06	0.04	0.05	0.05
Residual Fuel	0.20	0.09	0.10	0.07
Petroleum Subtotal	0.26	0.13	0.15	0.12
Natural Gas	5.11	5.64	6.66	6.93
Steam Coal	21.24	22.16	22.53	22.63
Nuclear Power	8.10	7.87	7.44	7.38
Renewable Energy 14/	4.22	4.99	6.03	7.61
Electricity Imports	0.46	0.30	0.39	0.32
Total	39.38	41.09	43.21	44.99
Total Energy Consumption				
Distillate Fuel	8.83	9.97	11.17	11.82
Kerosene	0.13	0.13	0.12	0.12
Jet Fuel 8/	3.88	4.46	5.12	5.82
Liquefied Petroleum Gas	3.02	3.15	3.27	3.33
Motor Gasoline 2/	17.86	18.90	19.22	19.37
Petrochemical Feedstocks	1.34	1.38	1.39	1.29
Residual Fuel	1.57	1.52	1.56	1.53
Other Petroleum 12/	4.58	5.00	5.22	5.43
Petroleum Subtotal	41.20	44.50	47.08	48.72
Natural Gas	25.68	27.50	29.43	30.75
Metallurgical Coal	0.69	0.65	0.60	0.56
Steam Coal	23.07	24.03	24.43	24.53
Net Coal Coke Imports	0.08	0.11	0.14	0.16
Coal Subtotal	23.84	24.78	25.17	25.26
Nuclear Power	8.10	7.87	7.44	7.38
Renewable Energy 15/	7.40	8.42	9.76	11.58
Liquid Hydrogen	0.00	0.00	0.01	0.02
Electricity Imports	0.46	0.30	0.39	0.32
Total	106.68	113.37	119.28	124.03

8/ Includes only kerosene type.
9/ Includes aviation gas and lubricants.
10/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
11/ M85 is 85 percent methanol and 15 percent motor gasoline.
12/ Includes unfinished oils, natural gasoline, motor gasoline blending compounds, aviation gasoline, lubricants, still gas, asphalt, road oil, petroleum coke, and miscellaneous petroleum products.
13/ Includes consumption of energy by all electric power generators for grid-connected power except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
14/ Includes conventional hydroelectric, geothermal, wood and wood waste, municipal solid waste, other biomass, petroleum coke, wind, photovoltaic and solar thermal sources. Excludes cogeneration. Excludes net electricity imports.
17/ Includes hydroelectric, geothermal, wood and wood waste, municipal solid waste, other biomass, wind, photovoltaic and solar thermal sources. Includes ethanol components of E85; excludes ethanol blends (10 percent or less) in motor gasoline. Excludes net electricity imports and nonmarketed renewable energy consumption for geothermal heat pumps, buildings photovoltaic systems, and solar thermal hot water heaters.

Table 2. Energy Prices by Sector and Source
(2000 Dollars per Million Btu, Unless Otherwise Noted)

	2005	2010	2015	2020
Residential	13.15	13.10	13.09	12.92
Primary Energy 1/	7.25	7.09	7.17	7.03
Petroleum Products 2/	9.45	9.87	10.18	10.26
Distillate Fuel	7.68	7.89	8.25	8.32
Liquefied Petroleum Gas..	12.90	13.42	13.61	13.75
Natural Gas	6.76	6.51	6.59	6.46
Electricity	22.27	22.27	21.72	21.16
Commercial	12.65	12.20	12.09	11.63
Primary Energy 1/	5.52	5.36	5.49	5.39
Petroleum Products 2/	6.10	6.34	6.65	6.72
Distillate Fuel	5.44	5.67	6.07	6.09
Residual Fuel	3.74	3.83	3.92	4.01
Natural Gas 3/	5.49	5.27	5.38	5.28
Electricity	19.98	19.16	18.87	18.37
Industrial 4/	5.65	5.78	5.97	5.96
Primary Energy	4.44	4.64	4.85	4.87
Petroleum Products 2/	6.36	6.71	6.97	7.05
Distillate Fuel	5.53	5.81	6.30	6.26
Liquefied Petroleum Gas..	8.27	8.76	8.98	9.19
Residual Fuel	3.56	3.64	3.73	3.85
Natural Gas 5/	3.19	3.21	3.37	3.30
Metallurgical Coal	1.60	1.55	1.52	1.46
Steam Coal	1.35	1.29	1.25	1.19
Electricity	12.53	12.12	12.07	11.83
Transportation	9.53	9.76	9.62	9.61
Primary Energy	9.51	9.74	9.59	9.60
Petroleum Products 2/	9.51	9.74	9.60	9.60
Distillate Fuel 6/	9.22	10.38	10.45	11.01
Jet Fuel 7/	5.51	5.88	6.26	6.39
Motor Gasoline 8/	10.95	10.84	10.51	10.29
Residual Fuel	3.39	3.48	3.57	3.67
Liquefied Petroleum Gas9/	13.97	14.43	14.54	14.42
Natural Gas 10/	6.27	7.28	7.89	7.94
Ethanol (E85) 11/	19.11	20.47	20.25	20.43
Electricity	16.54	18.00	18.89	16.97

1/ Weighted average price includes fuels below as well as coal.
2/ This quantity is the weighted average for all petroleum products, not just those listed below.
3/ Excludes independent power producers.
4/ Includes cogenerators.
5/ Excludes uses for lease and plant fuel.
6/ Low sulfur diesel fuel. Price includes Federal and State taxes while excluding county and local taxes.
7/ Kerosene-type jet fuel. Price includes Federal and State taxes while excluding county and local taxes.
8/ Sales weighted-average price for all grades. Includes Federal and State taxes and excludes county and local taxes.
9/ Includes Federal and State taxes while excluding county and local taxes.
10/ Compressed natural gas used as a vehicle fuel. Price includes estimated motor vehicle fuel taxes.
11/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).

Table 2. Energy Prices by Sector and Source (cont.)
(2000 Dollars per Million Btu, Unless Otherwise Noted)

	2005	2010	2015	2020
Electric Generators 13/				
Fossil Fuel Average	1.53	1.48	1.55	1.51
Petroleum Products	3.83	4.09	4.27	4.44
Distillate Fuel	4.92	5.16	5.56	5.53
Residual Fuel	3.52	3.57	3.63	3.72
Natural Gas	3.09	3.10	3.30	3.26
Steam Coal	1.13	1.05	1.01	0.96
Average Price to All Users 14/				
Petroleum Products 2/	8.75	9.06	9.04	9.08
Distillate Fuel	8.39	9.45	9.73	10.26
Jet Fuel	5.51	5.88	6.26	6.39
Liquefied Petroleum Gas	9.03	9.49	9.65	9.81
Motor Gasoline 8/	10.95	10.84	10.51	10.29
Residual Fuel	3.46	3.54	3.63	3.73
Natural Gas	4.38	4.29	4.43	4.38
Coal	1.15	1.07	1.03	0.98
Ethanol (E85) 11/	19.11	20.47	20.25	20.43
Electricity	18.58	18.11	17.84	17.44
Non-Renewable Energy Expend. by Sector (billion 2000 dollars)				
Residential	150.12	150.86	153.84	156.29
Commercial	113.63	119.78	128.95	134.92
Industrial	121.37	128.55	135.42	136.08
Transportation	279.02	314.79	333.59	350.57
Total Non-Renewable Expend...	664.14	713.99	751.81	777.87
Trans. Renew. Expenditures...	0.31	0.59	0.67	0.64
Total Expenditures	664.45	714.58	752.48	778.50

2/ This quantity is the weighted average for all petroleum products, not just those listed below.
8/ Sales weighted-average price for all grades. Includes Federal and State taxes and excludes county and local taxes.
11/ E85 is 85 percent ethanol (renewable) and 15 percent motor gasoline (nonrenewable).
13/ Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators.
14/ Weighted averages of end-use fuel prices are derived from the prices shown in each sector and the corresponding sectoral consumption.

Table 3. Renewable Energy Generating Capability and Generation
(Gigawatts, Unless Otherwise Noted)

	2005	2010	2015	2020
Elect.Generators (excl.cogen) 1/				
Net Summer Capability				
Conventional Hydropower	79.78	79.90	79.90	79.90
Geothermal 2/	3.10	5.25	7.97	10.84
Municipal Solid Waste 3/	3.53	3.93	4.21	4.42
Wood and Other Biomass 4/	1.66	1.92	2.13	2.47
Solar Thermal	0.34	0.36	0.39	0.41
Solar Photovoltaic	0.25	1.08	3.08	5.25
Wind	7.52	10.53	17.94	35.18
Total	96.18	102.96	115.62	138.47
Generation (billion kwh)				
Conventional Hydropower	301.24	301.09	300.47	299.89
Geothermal 2/	16.07	33.91	56.14	79.45
Municipal Solid Waste 3/	25.08	28.06	30.09	31.67
Wood and Other Biomass 4/	15.09	20.19	17.62	17.58
Dedicated Plants	9.26	11.00	12.31	14.61
Cofiring	5.84	9.19	5.31	2.97
Solar Thermal	0.90	0.96	1.05	1.12
Solar Photovoltaic	0.46	1.98	5.62	9.55
Wind	18.73	28.80	59.03	134.22
Total	377.58	415.00	470.02	573.48
Cogenerators 5/				
Net Summer Capability				
Municipal Solid Waste	0.51	0.51	0.51	0.51
Biomass	5.91	6.63	7.62	8.42
Total	6.42	7.14	8.13	8.93
Generation (billion kwh)				
Municipal Solid Waste	3.29	3.29	3.29	3.29
Biomass	33.73	38.05	44.05	48.99
Total	37.02	41.34	47.34	52.29
Other End-Use Generators 6/				
Net Summer Capability				
Conventional Hydropower 7/...	0.98	0.98	0.98	0.98
Geothermal	0.00	0.00	0.00	0.00
Solar Photovoltaic	0.08	0.08	0.08	0.08
Total	1.06	1.06	1.06	1.06
Generation (billion kwh)				
Conventional Hydropower 7/...	4.33	4.32	4.32	4.31
Geothermal	0.00	0.00	0.00	0.00
Solar Photovoltaic	0.18	0.18	0.18	0.18
Total	4.51	4.50	4.49	4.48

1/ Includes grid-connected utilities and nonutilities other than cogenerators. These nonutility facilities include small power producers and exempt wholesale generators.
2/ Includes hydrothermal resources only (hot water and steam).
3/ Includes landfill gas.
4/ Includes projections for energy crops after 2010.
5/ Cogenerators produce electricity and other useful thermal energy.
6/ Includes small on-site generating systems in the residential, commercial, and industrial sectors used primarily for own-use generation, but which may also sell some power to the grid. Excludes off-grid photovoltaics and other generators not connected to the distribution or transmission systems.
7/ Represents own-use industrial hydroelectric power.

Table 4. Carbon Dioxide Emissions by Sector and Source
(Million Metric Tons Carbon Equivalent, Unless Otherwise Noted)

	2005	2010	2015	2020
Residential				
Petroleum	25.8	24.0	22.4	21.0
Natural Gas	79.5	81.1	82.6	84.7
Coal	1.2	1.3	1.3	1.3
Electricity	219.6	219.8	226.2	230.0
Total	326.0	326.3	332.5	336.9
Commercial				
Petroleum	13.1	13.1	13.0	13.1
Natural Gas	55.0	60.6	67.2	76.0
Coal	1.7	1.8	1.9	2.0
Electricity	216.9	234.6	248.9	254.1
Total	286.7	310.2	331.0	345.2
Industrial 1/				
Petroleum	97.7	104.4	106.7	106.5
Natural Gas 2/	147.3	156.7	159.3	161.7
Coal	63.1	63.3	63.7	63.5
Electricity	182.8	193.7	197.5	194.5
Total	490.8	518.1	527.1	526.2
Transportation				
Petroleum 3/	559.3	615.1	659.7	691.0
Natural Gas 4/	11.9	13.8	16.1	18.0
Other 5/	0.1	0.1	0.1	0.1
Electricity	3.4	3.8	4.1	4.3
Total 3/	574.6	632.8	680.0	713.4
Total by Delivered Fuel				
Petroleum 3/	695.8	756.6	801.9	831.6
Natural Gas	293.7	312.2	325.1	340.4
Coal	66.0	66.5	66.8	66.7
Other 5/	0.1	0.1	0.1	0.1
Electricity	622.7	652.0	676.7	682.9
Total 3/	1678.2	1787.4	1870.6	1921.7
Electric Generators 6/				
Petroleum	5.4	2.7	3.1	2.4
Natural Gas	73.6	81.3	96.0	99.8
Coal	543.7	568.0	577.7	580.6
Total	622.7	652.0	676.7	682.9
Total by Primary Fuel 7/				
Petroleum 3/	701.2	759.3	804.9	834.0
Natural Gas	367.3	393.5	421.1	440.2
Coal	609.6	634.5	644.5	647.3
Other 5/	0.1	0.1	0.1	0.1
Total 3/	1678.2	1787.4	1870.6	1921.7

1/ Includes consumption by cogenerators.
2/ Includes lease and plant fuel.
3/ This includes international bunker fuel which, by convention are excluded from the international accounting of carbon dioxide emissions.
4/ Includes pipeline fuel natural gas and compressed natural gas used as vehicle fuel.
5/ Includes methanol and liquid hydrogen.
6/ Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy. Includes small power producers and exempt wholesale generators. Does not include emissions from the nonbiogenic component of municipal solid waste because under international guidelines these are accounted for as waste not energy.
7/ Emissions from electric power generators are distributed to the primary fuels.

Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs

FY 2004 Budget Request

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

(Appendix B Only)

Prepared by the

National Renewable Energy Laboratory

April 2004 NREL/TP-620-36404

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Appendix B – Building Technologies

The GPRA FY04 published documentation for Building Technologies and the Weatherization and Intergovernmental Program can be found at this link:

http://www.pnl.gov/main/publications/external/technical_reports/PNNL-14231.pdf

The Federal Energy Management Program (FEMP) metrics are estimated via a top-down approach, which are driven by forecasts of future energy consumption and prices. Federal metrics for regular buildings are aggregated from metrics developed for the Department of Defense (DOD), Department of Energy (DOE), General Services Administration (GSA), United States Postal Service (USPS), Veterans Affairs (VA), and all other agencies grouped together. Federal metrics for buildings housing energy intensive operations are estimated separately, but as a single group for the entire federal government. Metrics are not developed for exempt buildings, by definition.

Appendix B: PNNL-14231

PNNL 14231

Energy Efficiency and Renewable Energy
U.S. Department of Energy

Methodological Framework for Analysis of GPRA Metrics: Application to FY04 Projects in BT and WIP

April 2003

Prepared for EERE's Office of Planning, Budget Formulation, and Analysis
by Pacific Northwest National Laboratory

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PNNL-14231

Methodological Framework for Analysis of GPRA Metrics: Application to FY04 Projects in BT and WIP

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U.S. Department of Energy

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under Contract DE-AC06-76RL01830

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Executive Summary

Pacific Northwest National Laboratory (PNNL) estimated the fiscal year (FY) 2004 energy, environmental, and financial benefits (i.e., metrics) of the technologies and practices in the U.S. Department of Energy's (DOE's) former Office of Building Technology, State and Community Programs (BTS) within the DOE's Office of Energy Efficiency and Renewable Energy (EERE). During the development of the estimates, EERE went through a large-scale reorganization, resulting in the reallocation of the former BTS projects (along with the other former offices) into two new Program Offices: the Office of Building Technologies Program (BT) and the Office of Weatherization and Intergovernmental Program (WIP). The remainder of this document will refer to these projects as BT/WIP for the sake of simplicity.

This effort is referred to as GPRA Metrics because it stems from the requirements of the Government Performance and Results Act (GPRA) of 1993, which mandates the reporting of performance goals and measures. The benefits developed for EERE through the GPRA Metrics effort are submitted to EERE's Office of Planning, Budget Formulation, and Analysis (PBFA) as part of EERE's budget request. The GPRA estimates are also used in the formulation of EERE's performance measures.

This report includes sections that detail the approach and methodology used to estimate future energy, environmental, and financial benefits produced by technologies and practices supported by BT/WIP in the FY 2004. An overview describes the GPRA process and the models used to estimate savings. The body of the document describes the models used and the diffusion curve estimates. Appendixes contain tables of forecasted benefits for all projects through 2030, along with individual project characterizations and overall results of the FY 2004 GPRA effort.

Contents

Executive Summary iii

Contents v

1.0 Overview of the FY 2004 GPRA Metrics 1-1

1.1 Estimating the Energy Savings of BT/WIP Projects 1-1
1.2 Modeling Methods Used In Estimating Benefits 1-4
1.3 The National Research Council Methodology 1-5
1.4 Baseline Inputs 1-6
1.5 Adjustments to Estimates due to Budget Revisions 1-7
1.6 Calculating Employment and Income Impacts: The ImBuild Model 1-7
1.7 Contents of this Document 1-8

2.0 GPRA Metrics Methodology 2-1

2.1 BESET Methodology 2-1
2.1.1 Whole-Building or Envelope Project Approach 2-2
2.1.2 Equipment Project Approach 2-7
2.1.3 Lighting Project Approach 2-12
2.1.4 Other Components 2-19
2.2 General Methodology Using NEMS-PNNL 2-20
2.2.1 Commercial Demand 2-21
2.2.2 Residential Demand 2-22
2.2.3 Methodology for Market Transformation-Type Projects 2-22
2.2.4 Methodology for Equipment Projects 2-23
2.2.5 GPRA Envelope Calculations Using NEMS-PNNL 2-24
2.3 Spreadsheet Models 2-28
2.3.1 State Energy Project 2-28
2.3.2 Weatherization Assistance Project 2-28
2.3.3 Information Outreach 2-29
2.3.4 Building Codes 2-29
2.3.5 Lighting R&D: Lighting Controls 2-29
2.3.6 Space Conditioning and Refrigeration R&D: Commercial Refrigeration 2-29
2.3.7 Equipment Standards and Analysis: Distribution Transformers 2-30

3.0 Technology Diffusion Models – Application to Selected Energy-Efficient Products for Buildings 3-1

3.1 Scientific and Technical Approach 3-1
3.2 Background 3-1
3.3 Bass Diffusion Model 3-3
3.4 Estimation Issues 3-4
3.5 Results 3-5
3.5.1 Lighting Technologies 3-8
3.5.2 HVAC Technologies 3-12
3.5.3 Envelope and Other Technologies 3-18
3.6 Use of the Generic Curves within the GPRA Analysis 3-22

4.0 References 4-1
5.0 List of Terms 5-1
Appendix A – Building Technologies Program A-1
A.1 Energy Savings Analysis by Decision Unit A-1
A.2 FY 2004 GPRA Metrics for BT Based on FY 2004 BT Budget Request A-4
A.2.1 Scope of Analysis A-4
A.2.2 Comparison of FY 2003 GPRA Metrics with FY 2004 GPRA Metrics A-5
A.2.3 FY 2004 GPRA Metrics – Detailed Tables A-7
A.3 Residential Technology R&D A-27
A.4 Residential Building Codes A-30
A.5 Zero Energy Buildings A-34
A.6 Commercial Buildings Technology R&D A-37
A.7 Commercial Building Codes A-39
A.8 Lighting R&D A-43
A.9 Lighting R&D: Next Generation Lighting A-46
A.10 Space Conditioning and Refrigeration R&D A-51
A.11 Appliances and Emerging Technologies R&D A-60
A.12 Building Envelope R&D: Window Technologies A-71
A.13 Building Envelope R&D: Thermal Insulation and Building Materials A-75
A.14 Analysis Tools and Design Strategies A-79
A.15 Equipment Standards and Analysis A-82
Appendix B – Weatherization and Intergovernmental Program B-1
B.1 Energy Savings Analysis by Decision Unit B-1
B.2 FY 2004 GPRA Metrics for BT Based on FY 2004 BT Budget Request B-4
B.2.1 Scope of Analysis B-4
B.2.2 Comparison of FY 2003 GPRA Metrics with FY 2004 GPRA Metrics B-5
B.2.3 FY 2004 GPRA Metrics – Detailed Tables B-6
B.3 Weatherization Assistance Project B-27
B.4 State Energy Project B-33
B.5 Rebuild America B-37
B.6 Information Outreach B-40
B.7 Training and Assistance for Codes B-43
B.8 Energy Star B-44

Appendix C – Baseline Inputs for BESET C-1
C.1 Building Stock C-1
C.1.1 Commercial Building Stock Forecasts C-2
C.1.2 Residential Building Stock Forecasts C-13
C.2 Baseline Equipment Market Shares C-15
C.2.1 Residential Market Shares C-16
C.2.2 Commercial Market Shares C-26
C.3 Baseline Equipment Efficiencies C-33
C.3.1 Residential Equipment Efficiencies C-33
C.3.2 Commercial Equipment Efficiencies C-37
C.4 Baseline Equipment Life C-40
C.4.1 Residential Equipment Life C-40
C.4.2 Commercial Equipment Life C-41
C.5 End-Use Loads C-42
C.5.1 Residential End-Use Loads C-43
C.5.2 Commercial End-Use Loads C-46
C.6 Lighting Interactions Factors C-57
C.6.1 Case Definition – Baseline C-57
C.6.2 Case Definition – Variation from Baseline C-57
C.6.3 Specification C-58
C.6.4 Caveats/Constraints C-58
C.7 Emissions Coefficients C-62
C.8 Fuel Prices C-64
C.9 Electricity Conversion Factors C-66

1.0 Overview of the FY 2004 GPRA Metrics

Pacific Northwest National Laboratory (PNNL) estimated the projected FY 2004 energy, environmental, and financial benefits (i.e., metrics) of the technologies and practices in the U.S. Department of Energy's (DOE's) former Office of Building Technology, State and Community Programs (BTS) within the DOE's Office of Energy Efficiency and Renewable Energy (EERE). During the development of the estimates, EERE went through a large-scale reorganization, resulting in the former BTS projects (along with those of other former offices) being reallocated into two new program offices: the Office of Building Technologies Program (BT) and the Office of Weatherization and Intergovernmental Program (WIP). The remainder of this document will refer to these projects as BT/WIP for simplicity.

EERE initiated the metrics effort in 1994 to develop quantitative measures of project benefits and costs in response to the Government Performance and Results Act (GPRA) of 1993. The supporting analysis and data obtained through the metrics effort are used to estimate and validate progress toward strategic goals and objectives within BT/WIP and DOE, to communicate the benefits of EERE projects to all interested parties, and to defend the budget before Congress.

1.1 Estimating the Energy Savings of BT/WIP Projects

Energy savings for the FY 2004 GPRA metrics were based on the FY 2004 final budget request (dated 02/03/2003). Within each Program (BT and WIP), the budget request is comprised of levels of aggregation. Within this document, these levels are defined as:

- Decision Unit: the highest level of aggregation within the Program; decision units group like-types of projects together (e.g., Residential Buildings Integration projects primarily target residential buildings).
- Project: the budget line-item level. Projects may or may not be comprised of multiple activities for which benefits estimates are developed. In some cases, projects and decision units are equivalent (e.g., Weatherization Assistance).
- Activity: the product, technology, or service for which benefits estimates are developed. In some cases, activities and projects are equivalent (e.g., State Energy Project); in other cases, a project estimate is comprised of multiple activities (e.g., Space Conditioning and Refrigeration R&D includes multiple activities, such as Commercial Refrigeration, HVAC Distribution Systems, Advanced Electric Heat Pump Water Heaters, and Refrigerant Meters).

PNNL estimated the savings at the activity level and then aggregated them to the decision unit level. PNNL estimated WIP benefits for 12 activities, which rolled up into 6 projects and further into 3 WIP decision units. PNNL estimated BT benefits for 25 activities, which rolled up into 13 projects and further into 4 BT decision units. Table 1-1 shows the resulting 7 decision units, 19 BT and WIP projects, and 37 activities.

Table 1-1. Decision Units and Projects Evaluated for FY 2004 GPRA Metrics

Decision Unit	BT/WIP Projects Aggregated for GPRA FY 2004 Metrics	BT/WIP Activities
WIP – Weatherization Assistance	Weatherization Assistance Project	Weatherization Assistance Project
WIP – State Energy Project	State Energy Project	State Energy Project
WIP – Gateway Deployment	Rebuild America	Rebuild America
	Information Outreach	Energy Efficiency Information Outreach
	Training and Assistance for Codes	Building Codes Training & Assistance
	Energy Star	Clothes Washers Refrigerators Electric Water Heaters Gas Water Heaters Room Air Conditioner Compact Fluorescent Lights (CFLs) Dishwashers
BT – Residential Buildings Integration	Residential Technology R&D	Residential Buildings R&D
	Residential Building Codes	Residential Building Codes
	Zero Energy Buildings	Zero Energy Buildings
BT – Commercial Buildings Integration	Commercial Technology R&D	Commercial Buildings R&D
	Commercial Building Codes	Commercial Building Codes
BT – Emerging Technologies	Lighting R&D	Lighting R&D: Controls
	Next Generation Lighting Initiative	Next Generation Lighting Initiative
	Space Conditioning and Refrigeration R&D	Residential HVAC Distribution System Advanced Electric Heat Pump Water Heat Commercial Refrigeration Refrigerant Meter
	Appliances & Emerging Technologies R&D	Heat Pump Water Heater Roof Top Air Conditioning Gas Condensing Water Heater Recessed Can Lights R-Lamps
	Building Envelope R&D: Window Technologies	Electrochromic Windows Superwindows
	Building Envelope R&D: Thermal Insulation and Building Materials	Quick -Fill Walls R30/30 Year Roofs Moisture/Wet Insulation
	Analysis Tools and Design Strategies	Analysis Tools and Design Strategies
BT – Equipment Standards and Analysis	Equipment Standards and Analysis	Residential Gas Furnaces/Boilers EPAct Standards Distribution Transformers

No single model or approach is capable of capturing or adequately representing the diversity of activities supported by BT/WIP (not to mention the rest of the EERE portfolio). As such, PNNL has adopted a variety of analytical approaches including macro economic models, energy accounting models, and spreadsheets. This section briefly describes the analytical approaches used to estimate energy savings for the FY 2004 budget request for BT and WIP. Each project is characterized in greater detail in the appendixes to this document.

PNNL reports the benefits of BT/WIP projects and technologies at several different levels: they are provided at the Program (BT/WIP) level for use by senior EERE management in considering portfolio options; at the decision unit level for use by Program Managers to assess program direction and future progress toward goals and objectives; and at the project/activity level for use by project managers in planning and execution.

PNNL assessed the benefits for a limited number of defined metrics:

- Energy savings
- Environmental benefits
- Economic/financial metrics
- Employment and income impacts.

The BT/WIP projects produce many other benefits, including reductions in peak energy loads, enhanced security due to reduced oil demand, reduced energy costs for low-income households, and increased comfort and health in buildings; however, these are not currently measured as part of the GPRA process.

The environmental impacts that are estimated as part of the GPRA process are only those that directly related to the burning of fossil fuels; other impacts such as land use and localized water pollution are not measured. Within the economic metrics, the consumer cost savings (or energy cost savings) are simple monetizations of the energy savings and do not include the incremental cost of the new technology or practice; nor are they discounted. For both the environmental impacts and consumer cost savings, calculations are based on the EERE guidance for the GPRA Metrics effort (EERE 2002). Because environmental and economic benefits (energy cost savings) relate directly to projected energy savings, the balance of this overview focuses on just estimates of energy savings.

For most projects, PNNL further segmented the benefits estimates by building sector, building type, region, vintage, end use, fuel type, and type of equipment displaced and aggregated them to obtain the benefits for a project or technology. The project and decision unit structure used in this document reflect the organizational structure used in the FY 2004 budget request.

The benefits estimates are based on an evaluation of each project to determine the impact of successful project implementation (in other words, each project is assumed to meet its' stated goals). Our analysis considered project goals, technology characteristics (including performance and cost), the targeted market, and project milestones. Not all activities result in readily measurable energy savings as they are intermediate or enabling technologies or practices, or are contributing to the basic understanding (a "knowledge" benefit) of energy use in the building sector. For this GPRA analysis, we selected activities for which it was possible to develop measured energy savings.

The benefits estimates are developed based on a series of assumptions developed project-by-project. These input assumptions are critical to the analysis and are developed through an iterative process with the Project Managers. It should be noted that because BT/WIP projects are in different stages of maturity, there are varying degrees of corroborative studies available on which project information can be substantiated. Additionally, newer projects may not have estimates of future costs well-coordinated with performance estimates. For example, research projects would be expected to have more tenuous estimates of price and performance characteristics of potential products than deployment-related projects that feature products closer to market adoption. PNNL recognizes the varying levels of maturity and distance from market across projects and that the cost and performance characteristics improve as projects mature or as they near commercialization.

Because the estimates are produced for the budget request, the BT and WIP offices plan for the budget process two years in advance. For FY 2004, we based project characterizations on information gathered during interviews conducted throughout the summer of 2001. PNNL reviewed and revised the characterizations during meetings with project managers during the summer of 2002. The project characterizations in Appendixes A and B represent the results of those interviews, reviews, and revisions.

1.2 Modeling Methods Used In Estimating Benefits

PNNL calculated the BT/WIP GPRA estimates of benefits using one of three methods:

- A PNNL adaptation of the National Energy Modeling System (NEMS-PNNL)[a]
- Building Energy Savings Estimation Tool (BESET)
- Spreadsheets designed for a specific project.

NEMS-PNNL allows the costs and benefit characteristics of a technology and its market penetration to be linked. However, NEMS-PNNL has difficulty representing some BT/WIP technologies, such as the whole-building projects (projects that use a systems approach, looking at integration and interaction of building components such as roofs, walls, and equipment and seeking to optimize energy efficiency through consideration of these interactions), because NEMS-PNNL is designed to model specific technologies, not the impacts of groups of interacting technologies.

BESET was built specifically for estimating the benefits of BT/WIP projects and therefore allows various types of projects to be characterized, including whole-building, envelope, and equipment projects. BESET's major disadvantage is that the penetration rates (i.e., fraction of sales or fraction of installed base) are determined outside the model and therefore are not explicitly linked to the project's cost and benefit characteristics. In addition, BESET cannot model equipment that competes against more than one baseline equipment type.

The disadvantage of BESET's use of endogenous penetration rates is offset, in part, by the incorporation of technology diffusion curves within the analysis. In 1998, PNNL conducted a study to examine the historical market penetration (i.e., diffusion) for 10 energy-efficient products related to the buildings sector. Section 3.0 provides the most complete report of

[a] Any modification or alteration to the official NEMS model must be called out as such; for PNNL's GPRA effort, the modified version used is referred to as NEMS-PNNL.

that study. PNNL estimated diffusion models for each product based on the specification proposed by F.M. Bass (1969). Bass was the first to suggest the "S" curve or logistical functional form for the market diffusion of new products, and his concepts are still widely used in the marketing discipline today. We incorporated the resulting models into the GPRA metrics analysis for many of the projects and technologies not modeled within the NEMS framework. We designed the model development and empirical analysis to generate more credible predictions of the adoption process of important energy-efficiency technologies in the buildings sector. The technologies were placed into four separate categories: lighting, HVAC and refrigeration (HVAC/R), envelope, and other.

PNNL used spreadsheets to model projects not easily modeled in BESET or NEMS-PNNL. For example, because the codes and standards projects previously have developed their own set of spreadsheet tools for estimating impacts, PNNL adapted these tools for the GPRA estimation process. We describe each of the three methods used for deriving energy-saving estimates for the FY 2004 GPRA metrics in more detail in Section 2.0 of this document.

1.3 The National Research Council Methodology

A National Academy of Sciences report (NRC 2001) assessed the outcomes of energy efficiency and fossil energy research from 1978 to 2000. One of the council's recommendations for assessing research development and deployment projects was that "DOE should adopt an analytic framework similar to that used by this committee as a uniform methodology for assessing the benefits and costs of its R&D projects. DOE should also use this type of analytic framework in reporting to Congress under GPRA."

The National Research Council committee assumed that the private sector would have developed the technology in the absence of DOE five years after DOE realized the benefits (also known as the "5-year rule"). This assumption was made in order to more readily compare the impact of the various technologies analyzed, and was not based on empirical evidence or theory that most government efforts merely accelerate introduction of technologies into the marketplace. It should be noted that the NRC studied only R&D programs, so universal adoption of the 5-year rule by all projects, such as rulemaking and information efforts, goes beyond the NRC's intent. As such, this assumption was adopted, in part, as part of the uniform process for assessing prospective (future) benefits of EERE programs.

The calculation methodologies for the projects characterized using the National Research Council methodology were modified to remove the estimated benefits that would have occurred in the absence of DOE funding. This change was implemented within the BT/WIP estimates by determining the projects that act as acceleration-to-market activities rather than projects that would not have been developed or implemented in the absence of government funding (some projects, such as Weatherization Assistance and Appliance Standards, would most likely not be undertaken by the private sector, and therefore do not have a form of the 5-year rule applied to them). This approach diminishes the BT/WIP project savings in future years, presuming that the private sector is expanding its development and production of these technologies. Figure 1-1 illustrates how applying this acceleration methodology impacts a project's estimates in its most simplified state. Note that the bell-shaped curve in Figure 1-1 depicts the difference (the net benefit from DOE R&D, also shown as the shaded area) between the penetration without DOE R&D and the accelerated penetration with DOE R&D.

Further detail on how the methodology was implemented at the project level is contained in the appendixes' individual project characterizations, where applicable, and is referred to as the National Research Council (NRC) methodology. Because of the arbitrariness of a 5-year rule, PNNL used an "x-year rule," using judgment to assess the length of time the DOE project accelerated full deployment of a product.

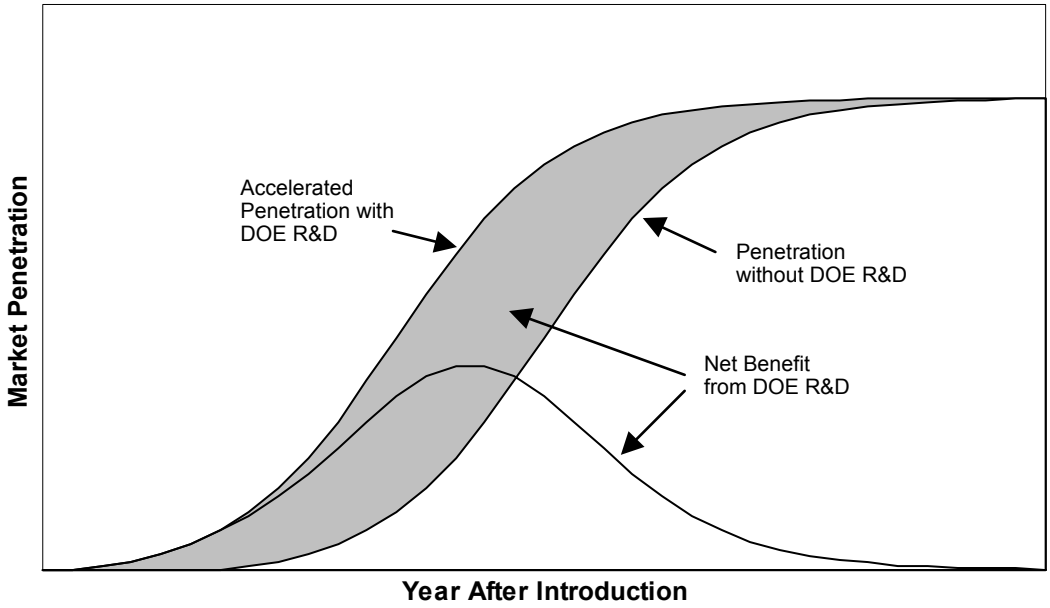

Figure 1-1. Impact of National Research Council Methodology (pure market acceleration case)

1.4 Baseline Inputs

The benefits estimates produced for the GPRA effort represent the estimated future impacts of activity funding. In order to produce the estimated impacts, baseline forecast assumptions must first be established. To the extent possible, the underlying assumptions about building stock forecasts, future equipment efficiencies, future market shares, and future end-use loads were consistent across tools (i.e., NEMS-PNNL, BESET, and spreadsheets). We accomplished consistency by drawing most of the baseline characterization data from forecasts produced by the Energy Information Administration (EIA), a statistical agency within DOE. For example, the same version of NEMS used in this document was used to produce EIA's *Annual Energy Outlook*.

BESET also has a baseline forecast characterization, which is drawn from NEMS-PNNL, EIA's *Annual Energy Outlook*, the "Residential Energy Consumption Survey," and the "Commercial Buildings Energy Consumption Survey." We verified the consistency of the baseline assumptions of the spreadsheet tools against EIA's data.

1.5 Adjustments to Estimates due to Budget Revisions

The budget formulation process involves much iteration, and the budget requested for various line items may change during that process. First, EERE develops an initial budget; next, an internal Review Budget (IRB) is developed in conjunction with the Chief Financial Officer; eventually, the budget proceeds to the Office of Management and Budget (OMB), and subsequent versions are developed based on an appeal of the OMB pass back. Finally, the budget is formally submitted by the President to Congress (referred to in this document as the final budget request).

The project characterizations driving the benefits estimates are developed through close interaction with the BT/WIP project managers. The characterizations require the project manager to make assumptions based on the requested level of funding, and the characterization then describes what would be accomplished at that level. However, because the budget request amount sometimes changes between the time that the characterization is developed and the time that the budget request is finalized, and also because changes occur between the final budget request (on which the final estimates are based) and the actual allocation, PNNL needs to be able to quickly recalculate the estimated benefits for the various projects.

For small changes in budget levels, PNNL introduces a basic "budget adjustment" to the project estimates. We assume that to get to X savings, a total of Y budget must be spent, where Y is the cumulative budget over the FY 2004-FY 2030 projection period. A change in the annual budget results in a change in the cumulative budget. Revised savings are calculated for each year using the formula: new cumulative budget in year z divided by old cumulative budget in year z. This adjustment mechanism implicitly suggests that either the fraction of expected sales or the performance of the project has changed but does not explicitly tie the change to one factor or the other.

For larger changes, we revisit the project inputs with the BT/WIP project managers to determine the impact of a reduced (or increased) budget. Options for adjusting the models include changing the year of market introduction, changing the impact on sales (market penetration), modifying the performance objective, and adding or removing tasks or technologies within the project (e.g., increased funding in Energy Star may result in developing an Energy Star rating for an additional technology).

The set of energy-savings estimates documented in this report was produced based on the final budget request for FY 2004 (dated 2/3/2003) and projected to FY 2030.

1.6 Calculating Employment and Income Impacts: The ImBuild Model

For DOE, PNNL also assesses the potential economic impacts of its portfolio of projects on national employment and income. PNNL uses a special purpose version of the IMPLAN input-output model called ImBuild II in a companion study covering the same projects analyzed for GPRA (Scott et al. 2003). That study reports energy savings, investments, and impacts on U.S. national employment and earned income by project for selected years to FY 2030. Energy savings and investments from these projects have the potential of creating 297,000 jobs and ~$4.2 billion in earned income (2002 $) by FY 2030. Scott et al. (2003) describes in more detail the employment and earned impacts results and modeling methodology.

The GPRA metrics analysis provides estimates of the energy savings and incremental cost to consumers for all BT and WIP projects, which are the primary inputs used to calculate the employment and income impacts of these programs. When consumer cost information was available, the costs of each BT and WIP project were compared with the next best available technology or design to derive incremental costs for each project. When consumer cost information was not readily available, the incremental cost of the project was derived based on the project's energy cost savings, assuming a payback period on the initial investment. The investment and cost assumptions for each project are included in the appendixes' individual project characterization, where applicable.

1.7 Contents of this Document

The remainder of this document consists of four sections and three appendixes. Section 2.0 provides more detailed information on the methodology behind the development of the GPRA benefits estimates. Section 3.0 provides more detailed information on the technology diffusion curves. Section 4.0 lists the references for the entire document, and Section 5.0 lists the terms used throughout the document.

Three appendixes contain the project-specific information used in estimating benefits. Appendix A summarizes the results and presents the inputs used in developing the BT estimates and presents characterizations of the BT projects. Appendix B summarizes the results and presents the inputs used in developing the WIP estimates and presents characterizations of the WIP projects. Appendix C presents the baseline data used by BESET.

2.0 GPRA Metrics Methodology

This section describes the calculation methodology used within BESET, NEMS-PNNL, and various spreadsheets to estimate the energy savings for BT and selected WIP projects.

2.1 BESET Methodology

BESET is a bottom-up accounting model that compares baseline energy use against specific EERE-sponsored technologies. BESET also is used to centrally collect, store, and report all results produced by all the various estimation methods. In addition to energy savings forecasts, these results also include such items as associated emissions reductions and necessary investment. Finally, BESET produces the input files needed for estimating employment impacts developed in a separate modeling environment (Scott et al. 2003).

BESET can estimate benefits for various projects: whole building, envelope, lighting, HVAC, and water heating. Beginning with the FY 2001 GPRA effort, BESET has been used primarily to model projects that target whole-building energy use. Although BESET can model equipment and envelope projects, those projects are primarily estimated using NEMS-PNNL.

To determine energy savings for specific BT/WIP projects, BESET requires information in the following areas:

- **Project Performance Goals.** The goals of each project are assessed in terms of energy savings (e.g., percent load reductions and equipment efficiency improvements) and used as inputs to BESET. PNNL gathers this information from each project by interviewing the project manager or reviewing project literature (e.g., technical reports, brochures, and websites).

- **Target Market.** Target markets are defined in terms of building sector (e.g., residential and commercial), building type (e.g., single family and educational), size (commercial only), income level (residential only), vintage (e.g., new or existing), and climate zone or region. Figure 2-1 illustrates the process used to define the project's targeted market segment within BESET, where certain building types, and building sizes are excluded from the mix (indicated with arrow curving downward), leaving a more specific market to target.

  Once the target market has been identified, PNNL determines penetration into that market using technology diffusion curves (discussed in Section 2.0). Within BESET, market penetration is defined as either the fraction of sales for equipment for new buildings or the fraction of installed base for existing buildings. The penetration model requires only the year of introduction into the market, an estimate of market penetration in 2020 (provided by BT/WIP project managers), and the selection of the most appropriate diffusion curve category (e.g., lighting or HVAC).

- **Private Investment (cost).** Estimates of private investment for both the baseline and the EERE technology or practice are entered into BESET. Ideally, the investment costs

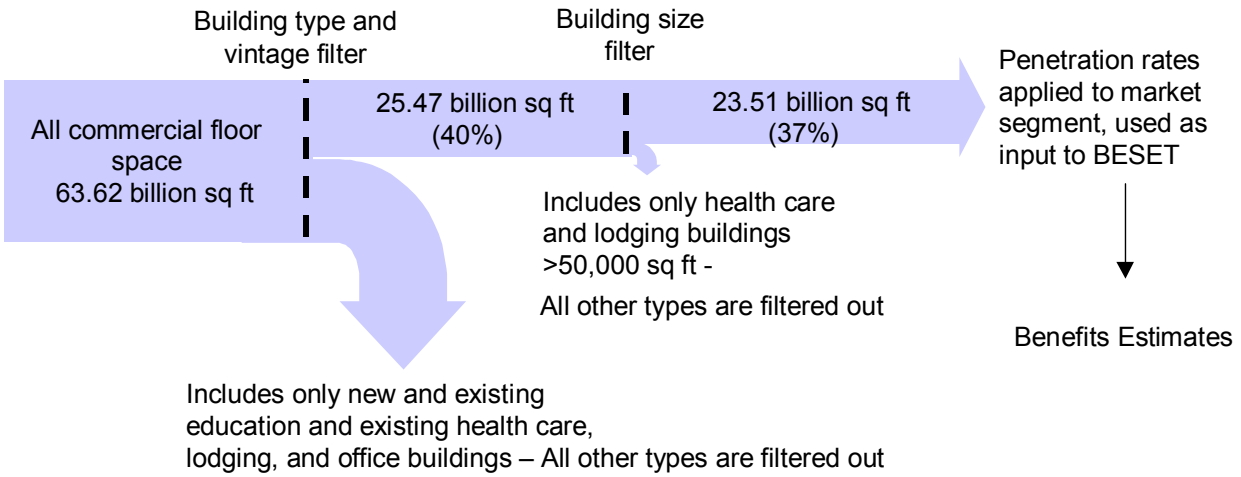

Figure 2-1. Developing the Market Segment (BESET)

would be considered when market penetration is developed; however, the current diffusion model used does not incorporate costs at this time. In addition to private investment, non-energy savings project benefits are also quantified when possible and entered into BESET.

All site-level energy savings and investment estimates are aggregated through a BESET-to-NEMS-PNNL interface. After this aggregation, BESET calculates the primary energy savings, associated emissions reductions, and the dollar value of the energy savings. BESET contains a report generator that aggregates the project- and technology-level benefits into the decision units. The aggregated information is submitted to EERE to be included in the GPRA metrics effort for all EERE sectors. Each of the BESET algorithm approaches is further documented below.

2.1.1 Whole-Building or Envelope Project Approach

This section addresses projects that target the building envelope, a whole-building design approach, or the total building system and that are modeled as improvements to the building envelope. Whole-building projects are characterized by a reduction in space conditioning and/or water heating load resulting from changes in the building system or envelope. The following projects are characterized by the whole-building approach:

- Rebuild America (in WIP – Gateway Deployment decision unit)
- Residential Buildings R&D (in BT – Residential Buildings decision unit)
- Zero Energy Buildings (in BT – Residential Buildings decision unit)
- Commercial Buildings R&D (in BT – Commercial Buildings Integration decision unit)
- Analysis Tools and Design Strategies (in BT – Emerging Technologies decision unit).

Calculating the energy savings associated with a whole-building project involves the following steps, which are discussed in the next subsections:

- Determine the size of the potential market.
- Determine the number of units affected by the BT/WIP project.
- Determine the base space conditioning and water heating end-use loads.

- Determine the space conditioning and water heating end-use loads after project implementation.
- Calculate the energy savings.

Determine Size of the Potential Market

Building stock estimates are used to determine the potential market for each project. Residential and commercial new and existing building stock totals for all years through FY 2020 were provided by EIA's *Annual Energy Outlook 2002*. The years 2021 through 2030 were extrapolated based on the annual growth from 2000 through 2020. The stock estimates have been developed for each market segment (e.g., building type, building vintage, and region) based on several assumptions bulleted below.

The building stock was disaggregated into north and south regions by using the EIA climate zones published in the "Residential Energy Consumption Survey" and the "Commercial Buildings Energy Consumption Survey." Climate zones 1 through 3 (i.e., zones with >4,000 heating-degree days) were designated as the north region, and zones 4 and 5 (i.e., zones with <4,000 heating-degree days) were defined as the south regions. Using this method, approximate percentages of north and south existing units and new construction were estimated:

- Residential single-family and multifamily housing
  - 60% of the existing building stock is in the north.
  - 40% of the existing building stock is in the south.
  - New stock is divided evenly across regions.

- Residential manufactured housing
  - 48% of the existing building stock is in the north.
  - 52% of the existing building stock is in the south.
  - 45% of the new building stock is in the north.
  - 55% of the new building stock is in the south.

- Commercial buildings
  - 59% of the existing building stock is in the north.
  - 41% of the existing building stock is in the south.
  - 55% of the new building stock is in the north.
  - 45% of the new building stock is in the south.

Using the assumptions listed above, we segmented the building stock numbers by building vintage and region. The base year is 2004, and all construction beginning with 2004 is considered new.

Each whole-building project has a specified target market: residential and/or commercial (and their subsets), new and/or existing vintages, and north and/or south regions. The target market for each project is described in that project's characterization, included in Appendixes A and B. The potential market for any project is the set of targeted buildings. For example, a project targeting single-family construction includes only the forecasts for new and existing single-family construction in the north and south.

Determine Number of Units Affected by the BT/WIP Project

The number of units affected by the BT or WIP project is calculated using the fraction of sales or fraction of installed base (hereafter referred to as penetration rate) that the project is expected to capture and the building stock. A penetration rate is applied to the appropriate market segment to compute the number of units impacted by the BT/WIP project, as follows:

$$u_{s,b,v,r,t} = P_{s,b,v,r,t} * S_{s,b,v,r,t} \qquad \textit{Equation 2-1}$$

Where u_t = number of units affected in year *t* (billion ft² or million households) for building sector *s*, building type *b*, vintage *v*, and region *r*

P_t = penetration rate in year *t* (provided in the project characterizations in Appendixes A and B) for building sector *s*, building type *b*, vintage *v*, and region *r*

S_t = building stock in year *t* (billion ft² or million households; see Appendix C, "Baseline Input for BESET") for building sector *s*, building type *b*, vintage *v*, and region *r*.

For new building stock, this product represents the number of impacted units in year *t*. However, for existing buildings, this calculation actually yields a cumulative number, as represented below in Equation 2-2:

$$U_t = \sum_{i=1}^{t} u_i \qquad \textit{Equation 2-2}$$

Where U_t = cumulative total units impacted through year *t*

u_i = number of units impacted in year *i*.

Within BESET, the existing building stock is defined as the total stock at the end of 2003/beginning of 2004, which subsequently gradually declines over time through events such as fires and demolition. The total units affected for existing buildings are, in effect, cumulative to that time period because penetration occurs against that same, entire (although gradually declining) stock each year. As a result, the number of existing-vintage installed units by year must be disaggregated. In other words, only the incremental units affected in a given year should be captured, and this additional step ensures that that occurs. Equation 2-3 explicitly shows this step:

$$u_t = U_t - U_{t-1} = \sum_{i=1}^{t} u_i - \sum_{i=1}^{t-1} u_i, \text{ for t} > 1 \qquad \textit{Equation 2-3}$$

All equations in the BESET methodology section are broken out by building sector, type, vintage, and region. To keep the subsequent equations readable, the subscripts for these categorizations are omitted.

Determine Base Space Conditioning and Water Heating End-Use Loads

End-use loads represent the baseline energy use per square foot (commercial) or per household (residential) for heating, cooling, water heating, and lighting uses. Before the FY 2002 GPRA effort, baseline end-use loads were averaged over all building types and distinguished only by building sector (commercial or residential), building vintage (new or

existing), and climate zone (north or south). To more accurately reflect the savings of projects targeting specific buildings, baseline end-use loads are now distinguished by building types (e.g., assembly, education, multifamily, etc.) as well as by vintage and climate zone. End-use loads were updated in June 2000 with energy use information derived from the Facility Energy Decision System (FEDS) (PNNL 2002) to reflect current energy technology and consumption behavior.

The performance improvements for whole-building projects are characterized by reductions in the space conditioning and water heating loads. Therefore, the base energy consumption does not have to be explicitly calculated. Instead, the load reduction is applied to the base load to determine the new load, and the resulting difference in loads is used to calculate energy savings.

Determine Space Conditioning and Water Heating End-Use Loads After Project Implementation

The performance inputs for whole-building projects are defined in terms of percent load reductions. The performance assumptions for each project are described in that project's characterization, included in Appendixes A and B. The load reductions are applied to the corresponding end-use load segment to determine the building-level load reductions by end use, as follows:

$$lr_{e,t} = L_{e,t} * R_{e,t} \qquad \textit{Equation 2-4}$$

Where $lr_{e,t}$ = building-level load reduction (in kBtu/ft^2 or MMBtu/household) for end-use *e*

$L_{e,t}$ = load in year t (kBtu/ft^2 or MMBtu/household) (see Appendix C) for end-use *e*

$R_{e,t}$ = percent load reduction in year *t* (provided in the project characterization) for end-use *e*.

The building-level load reductions are translated into aggregate load reductions by region as follows:

$$LR_{e,t} = lr_{e,t} * u_t \qquad \textit{Equation 2-5}$$

Where $LR_{e,t}$ = regional load reduction in year *t* for end-use *e* (TBtu)

$lr_{e,t}$ = building-level load reduction in year *t* for end-use *e*

u_t = total number of units impacted in year t (calculated in Equation 2-3 [existing] or Equation 2-1 [new]).

At this point, these potential load reductions are cumulated across years of the analysis. Each installation under the project continues to have savings impacts beyond the initial year of installation. The calculations, as shown in the equations below, provide aggregate load reductions in each year, while taking into account the effect of declining building stock for existing buildings. This declining building stock acts to reduce savings somewhat over time. For existing buildings:

$$CLR_{e,t} = \sum_{i=1}^{t} LR_{e,i} * \frac{S_t}{S_i}$$ *Equation 2-6*

Where $CLR_{e,t}$ = cumulative regional load reduction in year *t* for end-use *e* (TBtu)
$LR_{e,i}$ = regional load reduction in year *i* for end-use *e*
S_t = building stock in year *t*
S_i = building stock in year *i*.

For new buildings:

$$CLR_{e,t} = \sum_{i=1}^{t} LR_{e,i}$$ *Equation 2-7*

Where $CLR_{e,t}$ = cumulative regional load reduction in year *t* for end-use *e* (TBtu)
$LR_{e,i}$ = regional load reduction in year *i* for end-use *e*.

Calculate Energy Savings

The cumulative regional load reductions must be translated into regional energy savings, requiring baseline assumptions for existing equipment efficiencies and existing equipment market shares. Equipment stock efficiencies were developed from EIA's 1995 *Annual Energy Outlook* and input from project managers. Equipment market shares are broken out by market segment and are estimated based on the 1997 "Residential Energy Consumption Survey," the 1995 "Commercial Buildings Energy Consumption Survey," and original PNNL efforts by Dave Belzer. Because of the lack of a consistent, comprehensive source, the baseline assumptions for equipment efficiencies and equipment shares are not updated annually, but rather on a case-by-case basis as information becomes available. Where applicable, the assumed stock efficiency was increased to meet equipment standards, as these would be the minimum efficiency levels required by law.

First, the cumulative regional load reductions are divided by the baseline existing equipment efficiencies, yielding potential energy savings by equipment type and end use. The potential energy savings assume that each equipment type has 100% of the market, so the actual equipment market shares must then be applied. The market share for each equipment type is multiplied by the potential energy savings to determine the actual energy savings. Equation 2-8 illustrates the energy savings by equipment type and end use calculations:

$$ES_{e,f,q,t} = \frac{CLR_{e,t}}{e_{e,f,q,t}} * M_{e,f,q,t}$$ *Equation 2-8*

Where $ES_{e,f,q,t}$ = energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu/Yr)
$CLR_{e,t}$ = cumulative regional load reduction in year *t* for end-use *e*
$e_{e,f,q,t}$ = equipment efficiency in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$M_{e,f,q,t}$ = market share in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

The savings calculated are aggregated by building sector, type, vintage, region, and fuel type to determine the total site electric savings, total natural gas savings, and total oil savings.

2.1.2 Equipment Project Approach

This section addresses projects that target equipment, other than lighting. Equipment projects are characterized using new equipment efficiency. The following projects are characterized using the equipment approach:

- Space Conditioning and Refrigeration R&D: Residential HVAC Distribution System (in BT – Emerging Technologies decision unit)
- Space Conditioning and Refrigeration R&D: Advanced Electric Heat Pump Water Heater (in BT – Emerging Technologies decision unit)
- Space Conditioning and Refrigeration R&D: Refrigerant Meter (in BT – Emerging Technologies decision unit).

Calculating the energy savings associated with an equipment project involves the following steps, which are discussed in the next subsections:

- Determine the size of the potential market and the number of units affected by the BT/WIP project.
- Calculate adjustments to the potential market and units affected.
- Determine the base energy consumption of impacted units.
- Determine the energy consumption of impacted units after project implementation.
- Calculate the energy savings.

Determine Size of Potential Market and Number of Units Affected by the BT/WIP Project

Estimates of building stock, base equipment market share and life, project equipment life, and penetration rates all play a role in determining the potential market and the number of units affected by BT/WIP equipment projects. Unlike the relatively straightforward calculations for the whole building projects, equipment calculations are much more complicated. The primary driver behind this is the fact that equipment projects involve devices that fail within a shorter time-frame, relative to the whole building projects, and must be replaced during the analysis period. Despite the additional level of complexity, the initial steps are similar.

Each equipment project has a specified target market – residential and/or commercial (and their subsets), new and/or existing vintages, and north and/or south regions. The target market for each project is described in that project's characterization, included in the appendixes to this document.

For the initial calculation, the potential market for any equipment project is, for the targeted building set, the product of the equipment stock and the base equipment replacement factor. The equipment stock is derived through multiplication of the building stock and the equipment market shares. A replacement factor is calculated as the inverse of base equipment life, and indicates the frequency of required replacements. The derivations of equipment stock and the potential market are shown in Equations 2-9 and 2-10, respectively.

$$SE_{e,f,q,t} = S_t * M_{e,f,q,t} \qquad \textit{Equation 2-9}$$

Where $SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billions ft² or million households)
S_t = building stock in year *t* (billion ft² or million households)
$M_{e,f,q,t}$ = equipment market share in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

$$PM_{e,f,q,t} = SE_{e,f,q,t} * \frac{1}{BLife_{e,f,q}} = SE_{e,f,q,t} * BR_{e,f,q} \qquad \textit{Equation 2-10}$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households)
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households)
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$BR_{e,f,q}$ = base equipment replacement factor for end-use *e*, fuel type *f*, and equipment type *q*.

To initially calculate the number of units affected by the BT/WIP project, the penetration rate is applied to the potential market, as follows:

$$u_{e,f,q,nf,t} = P_{e,f,q,nf,t} * PM_{e,f,q,t} \qquad \textit{Equation 2-11}$$

Where $u_{e,f,q,nf,t}$ = number of units affected in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf* (billion ft² or million households)
$P_{e,f,q,nf,t}$ = penetration rate in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf* (provided in the project characterization)
$PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households).

In contrast to the case for whole-building projects, the basic units calculation for equipment illustrated here does not require any special handling of existing buildings. With whole-building projects, penetration occurs against the entire building stock. For equipment projects, penetration occurs against only a portion of the building stock because of the use of a replacement factor. As a result, the existing vintage cumulative problem described in the whole-building approach does not exist here.

Calculate Adjustments to Potential Market and Units Affected

While this initial calculation of potential market and impacted units outlined above is fairly simple, the following steps are much more involved. Because base equipment life and project equipment life may differ, a project installation (unit impacted) in year *t* may impact the potential market in future years, which in turn affects project installations in future years. Handling this issue requires an iterative process. The results of the calculations of the previous section serve as inputs to this process.

The issue of differing base and BT/WIP-sponsored equipment lives is not the only complicating factor. The annual (rather than cumulative) nature of new building stock numbers requires unique coding to ensure recompetition of new vintage installations upon failure. This treatment renders new vintage handling consistent with that for existing buildings. Without this added treatment, new vintage installations (whether base equipment or project equipment) would always be replaced with like equipment upon failure, ignoring a valid possibility of additional project penetration.

Beginning with the existing vintage case for the potential market, the calculations of this iterative updating process are outlined below as a series of conditional statements:

$$PM_{e,f,q,t} =$$
$$\left(If\ (t\text{-}1) \geq BLife_{e,f,q}\ then\ \frac{PM_{e,f,q,(t\text{-}BLife_{e,f,q})}}{SE_{e,f,q,(t-BLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ PM_{e,f,q,t} \right)$$
$$- \left(If\ (t\text{-}1) \geq BLife_{e,f,q}\ then\ \frac{u_{e,f,q,nf,(t\text{-}BLife_{e,f,q})}}{SE_{e,f,q,(t\text{-}BLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ 0 \right) \qquad \textit{Equation 2-12}$$
$$+ \left(If\ (t\text{-}1) \geq PLife_{e,f,q}\ then\ \frac{u_{e,f,q,nf,(t\text{-}PLife_{e,f,q})}}{SE_{e,f,q,(t\text{-}PLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ 0 \right)$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$PLife_{e,f,q}$ = project equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$u_{e,f,q,nf,t}$ = number of units affected in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf*.

.

For new buildings: *Equation 2-13*

$$PM_{e,f,q,t} = \left(SE_{e,f,q,t}\right) + \left(If\ (t\text{-}1) \geq BLife_{e,f,q}\ then\ PM_{e,f,q,(t-BLife_{e,f,q})} * \left(1\text{-}P_{e,f,q,nf,(t\text{-}BLife_{e,f,q})}\right),\ else\ 0\right)$$
$$+ \left(If\ (t\text{-}1) \geq PLife_{e,f,q}\ then\ u_{e,f,q,nf,(t-PLife_{e,f,q})},\ else\ 0\right)$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$PLife_{e,f,q}$ = project equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$P_{e,f,q,nf,t}$ = penetration rate in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf*
$u_{e,f,q,nf,t}$ = number of units affected in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf*.

These calculations are carried out for all years sequentially for each market segment, beginning with the first year. After the potential market is recalculated for a given year, the impacted units for that year must be recalculated, using Equation 2-11.

Determine Base Energy Consumption of Impacted Units

Building-level base energy consumption is calculated by dividing end-use loads by base equipment efficiencies. End-use loads represent the baseline service requirements per square foot (commercial) or per household (residential) for heating, cooling, and water heating. As such, they must be divided by an efficiency to determine energy consumption:

$$bc_{e,f,q,t} = \frac{L_{e,t}}{e_{e,f,q,t}} \qquad \textit{Equation 2-14}$$

Where $bc_{e,f,q,t}$ = building-level base consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (kBtu/ft^2 or MMBtu/household)

$L_{e,t}$ = end-use load in year *t* for end-use *e* (kBtu/ft^2 or MMBtu/household) (see Appendix C)

$e_{e,f,q,t}$ = base equipment efficiency in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

Multiplying this result by the number of impacted units yields regional base consumption yields the following:

$$BC_{e,f,q,t} = bc_{e,f,q,t} * u_{e,f,q,t} \qquad \textit{Equation 2-15}$$

Where $BC_{e,f,q,t}$ = regional base consumption of impacted units in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$bc_{e,f,q,t}$ = building-level base consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (kBtu/ft^2 or MMBtu/household)

$u_{e,f,q,t}$ = total number of units impacted in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft^2 or million households).

Because the final goal is calculating energy savings associated with impacted units, deriving total base consumption is not necessary; rather base consumption associated with impacted units only suffices.

At this point, the consumption figures are cumulated across years of the analysis. Each piece of equipment continues to consume energy throughout its lifetime. Therefore, in a given year, consumption may result from equipment installed in several previous years as well. The calculations, as shown in the equations below, provide aggregate energy consumption in each year, while taking into account the effect of declining building stock for existing buildings. This declining building stock acts to reduce consumption somewhat over time. To compare the base and project equipment's energy usage appropriately, the base consumption is cumulated over the lifetime of the project equipment. For existing buildings:

$$CBC_{e,f,q,t} = \sum_{i=(t-PLife_{e,f,q})}^{t} BC_{e,f,q,i} * \frac{S_t}{S_i}, \text{ for t > PLife} \qquad \textit{Equation 2-16}$$

$$CBC_{e,f,q,t} = \sum_{i=1}^{t} BC_{e,f,q,i} * \frac{S_t}{S_i}, \text{ for t} \leq \text{PLife}$$ *Equation 2-17*

Where $CBC_{e,f,q,t}$= cumulative regional base energy consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (Tbtu)

$BC_{e,f,q,i}$ = regional base energy consumption in year *i* for end-use *e*, fuel type *f*, and equipment type *q*

S_t = building stock in year *t*

S_i = building stock in year *i*

$PLife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*.

For new buildings:

$$CBC_{e,f,q,t} = \sum_{i=(t-PLife_{e,f,q})}^{t} BC_{e,f,q,i}, \text{ for t} > \text{PLife}$$ *Equation 2-18*

$$CBC_{e,f,q,t} = \sum_{i=1}^{t} BC_{e,f,q,i}, \text{ for t} \leq \text{PLife}$$ *Equation 2-19*

Where $CBC_{e,f,q,t}$= cumulative regional base energy consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (Tbtu)

$BC_{e,f,q,i}$ = regional base energy consumption in year *i* for end-use *e*, fuel type *f*, and equipment type *q*

$Plife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*.

Determine Energy Consumption of Impacted Units After Project Implementation

The performance inputs for equipment projects are defined in terms of new equipment efficiencies. The performance assumptions for each project are described in that project's characterization, included in Appendix A (BT projects) and Appendix B (WIP projects) of this document. A directly parallel process to that described in the previous section is used to calculate consumption associated with the project equipment. In this case, the initial step uses the performance inputs for the project equipment, rather than the base equipment efficiency:

$$pc_{e,nf,q,t} = \frac{L_{e,t}}{p_{e,nf,q,t}}$$ *Equation 2-20*

Where $pc_{e,nf,q,t}$ = building-level program consumption in year *t* for end-use *e*, new fuel *nf*, and equipment type *q* (kBtu/ft^2 or MMBtu/household)

$L_{e,t}$ = load in year *t* for end-use *e* (kBtu/ft^2 or MMBtu/household) (see Appendix C)

$p_{e,nf,q,t}$ = project equipment efficiency in year *t* for end-use *e*, new fuel *nf*, and equipment type *q*.

All other steps toward deriving cumulative regional project energy consumption, CPC_t, are identical to those described in the previous section.

Calculate Energy Savings

With equipment projects, a significant probability of fuel switching exists. To calculate energy savings where the base fuel type is the same as the BT/WIP project fuel type, project consumption is subtracted from base consumption:

$$ES_{e,f,q,t} = CBC_{e,f,q,t} - CPC_{e,nf,q,t} \qquad \textit{Equation 2-21}$$

Base fuel savings where the base fuel type is different from the project fuel type are simply the entire base fuel use:

$$ES_{e,f,q,t} = CBC_{e,f,q,t} \qquad \textit{Equation 2-22}$$

Project fuel savings where the base fuel type is different from the project fuel type are recorded as the negative of project consumption:

$$ES_{e,nf,q,t} = -CPC_{e,nf,q,t} \qquad \textit{Equation 2-23}$$

Where $ES_{e,f,q,t}$ = energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$CBC_{e,f,q,t}$ = cumulative regional base energy consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$CPC_{e,nf,q,t}$ = cumulative regional program energy consumption in year *t* for end-use *e*, new fuel *nf*, and equipment type *q* (TBtu).

These savings (with some being negative) are combined and summed over end uses and equipment to provide the final net energy savings. The final net energy savings are aggregated by building sector, type, vintage, region, and fuel type to determine the total site electric savings, total natural gas savings, and total oil savings.

2.1.3 Lighting Project Approach

This section addresses projects targeting lighting that are modeled using BESET. Lighting projects are characterized by a change in the measure of light output per unit of power, or lumens per watt. The following projects are characterized by the lighting approach:

- Energy Star: CFLs (in WIP – Gateway Deployment decision unit)
- Appliances & Emerging Technologies R&D: Recessed can lights (in BT – Emerging Technologies decision unit)
- Appliances & Emerging Technologies R&D: R-Lamps (in BT – Emerging Technologies decision unit).

Calculating the energy savings associated with a lighting project involves the following steps, which are discussed in the next subsections:

- Determine the size of the potential market and the number of units affected by the BT/WIP project.
- Calculate adjustments to the potential market and units affected.
- Calculate the lighting energy savings.

- Calculate the heating and cooling interactive effects factors.
- Calculate the change in space conditioning energy use due to interactive effects.
- Derive the final energy savings.

Determine Size of Potential Market and Number of Units Affected by the BT/WIP Project

Unlike whole-building projects, lighting projects involve equipment that fails and must be replaced during the analysis period. Despite this additional level of complexity, the initial steps are similar.

Each lighting project has a specified target market: residential and/or commercial (and their subsets), new and/or existing vintages, and north and/or south regions. The target market for each project is described in that project's characterization, included in Appendixes A and B.

For the initial calculation, the potential market for any lighting project is, for the targeted building set, the product of the equipment stock and the base equipment replacement factor. The equipment stock is derived by multiplying the building stock and the equipment market shares. A replacement factor is calculated as the inverse of base equipment life and indicates the frequency of required replacements. The derivations of equipment stock and the potential market are shown in Equations 2-24 and 2-25, respectively.

$$SE_{e,f,q,t} = S_t * M_{e,f,q,t} \qquad \textit{Equation 2-24}$$

Where $SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households)
S_t = building stock in year *t* (billion ft² or million households)
$M_{e,f,q,t}$ = equipment market share in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

$$PM_{e,f,q,t} = SE_{e,f,q,t} * \frac{1}{BLife_{e,f,q}} = SE_{e,f,q,t} * BR_{e,f,q} \qquad \textit{Equation 2-25}$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households)
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households)
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$BR_{e,f,q}$ = base equipment replacement factor for end-use *e*, fuel type *f*, and equipment type *q*.

To initially calculate the number of units affected by the BT/WIP project, the penetration rate is applied to the potential market, as follows:

$$u_{e,f,q,t} = P_{e,f,q,t} * PM_{e,f,q,t} \qquad \textit{Equation 2-26}$$

Where $u_{e,f,q,t}$ = number of units affected in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft2 or million households)
$P_{e,f,q,t}$ = penetration rate in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (provided in the project characterization)
$PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft2 or million households).

In contrast to whole-building projects, the basic units calculation for lighting illustrated here does not require any special handling of existing buildings. With whole-building projects, penetration occurs against the entire building stock. For lighting, penetration occurs against only a portion of the building stock because a replacement factor is used. As a result, the existing vintage cumulative problem described in the whole-building approach does not exist here.

Calculate Adjustments to the Potential Market and Units Affected

While this initial calculation of potential market and impacted units outlined above is fairly simple, the following steps are much more involved. Because base equipment life and project equipment life may differ (e.g., lives of CFLs and incandescents), a project installation (unit impacted) in year *t* may impact the potential market in future years, which in turn affects project installations in future years. Handling this issue requires an iterative process. The results of the calculations of the previous section serve as inputs to this process.

The issue of differing base and BT/WIP project lives is not the only complicating factor. The annual (rather than cumulative) nature of new building stock numbers requires unique coding to ensure recompetition of new vintage installations upon failure. This treatment renders new vintage handling consistent with that for existing buildings. Without this added treatment, new vintage installations (whether base equipment or project equipment) would always be replaced with like equipment upon failure, ignoring a valid possibility of additional project penetration.

Beginning with the existing vintage case for the potential market, the calculations of this iterative updating process are outlined below as a series of conditional statements:

$$
\begin{aligned}
PM_{e,f,q,t} = \\
&\left(If\ (t\text{-}1) \geq BLife_{e,f,q}\ then\ \frac{PM_{e,f,q,(t\text{-}BLife_{e,f,q})}}{SE_{e,f,q,(t-BLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ PM_{e,f,q,t} \right) \\
&- \left(If\ (t\text{-}1) \geq BLife_{e,f,q}\ then\ \frac{u_{e,f,q,(t\text{-}BLife_{e,f,q})}}{SE_{e,f,q,(t\text{-}BLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ 0 \right) \\
&+ \left(If\ (t\text{-}1) \geq PLife_{e,f,q}\ then\ \frac{u_{e,f,q,(t\text{-}PLife_{e,f,q})}}{SE_{e,f,q,(t\text{-}PLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ 0 \right)
\end{aligned}
\qquad \textit{Equation 2-27}
$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*

$PLife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$u_{e,f,q,t}$ = number of units affected in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

For new buildings: *Equation 2-28*

$$PM_{e,f,q,t} = \left(SE_{e,f,q,t}\right) + \left(If\ (t\text{-}1) \geq BLife_{e,f,q}\ then\ PM_{e,f,q,(t-BLife_{e,f,q})} * \left(1\text{-}P_{e,f,q,(t\text{-}BLife_{e,f,q})}\right),\ else\ 0\right)$$
$$+ \left(If\ (t\text{-}1) \geq PLife_{e,f,q}\ then\ u_{e,f,q,(t-PLife_{e,f,q})},\ else\ 0\right)$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$PLife_{e,f,q}$ = project equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$P_{e,f,q,t}$ = penetration rate in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$u_{e,f,q,t}$ = number of units affected in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

These calculations are carried out for all years sequentially for each market segment, beginning with the first year. After the potential market is recalculated for a given year, the impacted units for that year must be recalculated, using Equation 2-26 above.

Calculate Lighting Energy Savings

The performance inputs for lighting projects are defined in terms of light output per unit of power, or lumens per watt. The performance assumptions for each project are described in that project's characterization, included in Appendixes A and B. Ratios of the base and project efficacies are applied to the corresponding end-use load segment to determine the building-level energy savings by end use, as follows:

$$es_{e,f,q,t} = \left(1 - \frac{e_{base,e,f,q,t}}{e_{project,e,f,q,t}}\right) * L_{e,t} \qquad \textit{Equation 2-29}$$

Where $es_{e,f,q,t}$ = building-level energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (in kWh/ft² or kWh/household)
$L_{e,t}$ = load in year *t* for end-use *e* (kWh/ft² or kWh/household) (see Appendix C)
$e_{project,e,f,q,t}$ = efficacy of program equipment in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (lumens/watt) (provided in the project characterization)
$e_{base,e,f,q,t}$ = efficacy of base case equipment in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (lumens/watt).

Unlike the calculations for whole-building projects, market shares do not have to be incorporated or efficiencies do not have to be divided to derive lighting energy savings from end-use load data. The reason is that the load data for the lighting end-use are actually consumption figures, whereas load data for other end uses represent service requirements.

If the lighting load were to be input into BESET in a similar fashion as the other end uses, the data would be entered in lumens/ft^2 rather than the current kWh/ft^2.

After the building-level lighting energy savings are converted to kBtu/ft^2 and MMBtu/household, they are then translated into aggregate lighting energy savings by region as follows:

$$ES_{e,f,q,t} = es_{e,f,q,t} * u_{e,f,q,t} \qquad \textit{Equation 2-30}$$

Where $ES_{e,f,q,t}$ = regional energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)
$es_{e,f,q,t}$ = building-level energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$u_{e,f,q,t}$ = total number of units impacted in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (calculated in Equation 2-26).

At this point, these energy savings are cumulated across years of the analysis. Each installation under the project continues to have savings impacts beyond the initial year of installation. Installed lighting continues to generate savings until the end of its life. Therefore, in a given year, savings may be realized from project equipment installed in several previous years as well. The calculations, as shown in the equations below, provide aggregate energy savings in each year, while taking into account the effect of declining building stock for existing buildings. This declining building stock acts to reduce savings somewhat over time. For existing buildings, the calculations are as follows:

$$CES_{e,f,q,t} = \sum_{i=(t-PLife_{e,f,q})}^{t} ES_{e,f,q,i} * \frac{S_t}{S_i}, \text{ for t} > \text{PLife} \qquad \textit{Equation 2-31}$$

$$CES_{e,f,q,t} = \sum_{i=1}^{t} ES_{e,f,q,i} * \frac{S_t}{S_i}, \text{ for t} \leq \text{PLife} \qquad \textit{Equation 2-32}$$

Where $CES_{e,f,q,t}$ = cumulative regional energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (Tbtu)
$ES_{e,f,q,i}$ = regional energy savings in year *i* for end-use *e*, fuel type *f*, and equipment type *q*
S_t = building stock in year *t*
S_i = building stock in year *i*
$PLife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*.

For new buildings:

$$CES_{e,f,q,t} = \sum_{i=(t-PLife_{e,f,q})}^{t} ES_{e,f,q,i}, \text{ for t} > \text{PLife} \qquad \textit{Equation 2-33}$$

$$CES_{e,f,q,t} = \sum_{i=1}^{t} ES_{e,f,q,i}, \text{ for t} \leq \text{PLife} \qquad \textit{Equation 2-34}$$

Where $CES_{e,f,q,t}$ = cumulative regional energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$ES_{e,f,q,i}$ = regional energy savings in year *i* for end-use *e*, fuel type *f*, and equipment type *q*
$PLife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*.

Calculate Heating and Cooling Interactive Effects Factors

A change in lighting consumption significantly impacts other end uses as well. As more efficient lighting is incorporated in buildings, heating loads can be expected to increase, while cooling loads should be reduced. BESET incorporates interactive effects coefficients as inputs, which are used to derive heating and cooling load change factors. For more information on the derivation of the coefficients, see Appendix C. As Appendix C describes, the interactive factors are calculated using the following equations:

$$\Delta heat = a * \Delta L^b \qquad \textit{Equation 2-35}$$

$$\Delta cool = c * \Delta L^2 + d * \Delta L \qquad \textit{Equation 2-36}$$

Where a, b, c, and d are the interactive effects coefficients
$\Delta heat$ = the fractional change in heating load
$\Delta cool$ = the fractional change in cooling load
ΔL = the percentage reduction in lighting load.

To calculate the necessary input, ΔL, the baseline lighting consumption first must be determined. For existing buildings:

$$BC_t = L_t * S_t \qquad \textit{Equation 2-37}$$

Where BC_t = base lighting consumption in year *t* (billion kWh for commercial and industrial, million kWh for households)
L_t = lighting end-use load in year *t* (kWh/ft^2 or kWh/household)
S_t = building stock in year *t* (billion ft2 or million households).

Because new building stock is annual, rather than cumulative, the calculation requires summation of the energy usage, which yields consumption of all new buildings in year *t*. For new buildings:

$$BC_t = \sum_{i=1}^{t} L_i * S_i \qquad \textit{Equation 2-38}$$

Where BC_t = base lighting consumption in year *t* (billion kWh for commercial and industrial, million kWh for households)
L_i = lighting end-use load in year *i* (kWh/ft^2 or kWh/household)
S_i = building stock in year *i* (billion ft^2 or million households).

After the base consumption results are converted to TBtu, the percentage reduction in lighting load can be calculated. The previously calculated cumulative regional lighting energy savings serves as the numerator:

$$\Delta L = \left(\frac{CES_t}{BC_t} \right) * 100 \qquad \textit{Equation 2-39}$$

Where ΔL = the percentage reduction in lighting load
CES_t = cumulative regional lighting energy savings in year t (TBtu)
BC_t = base lighting consumption in year t (TBtu).

At this point, the required components for calculating the interactive effects factors are available. Using Equations 2-35 and 2-36, Δheat and Δcool are computed.

Calculate Change in Space Conditioning Energy Use Due to Interactive Effects

The load changes from interactive effects are calculated by applying the interactive effects factors to the cumulative regional lighting energy savings (calculated previously in Equations 2-31 through 2-34). As noted earlier, as lighting efficiency increases, cooling loads decrease and heating loads increase. As a result, the calculated values for Δheat are positive, and those for Δcool are negative. Because the load reduction, rather than the change in load, is the desired output, a sign change is applied in the following calculation:

For heating:

$$ILR_{e,f,q,t} = CES_{e,f,q,t} * (-\Delta heat) \qquad \textit{Equation 2-40}$$

For cooling:

$$ILR_{e,f,q,t} = CES_{e,f,q,t} * (-\Delta cool) \qquad \textit{Equation 2-41}$$

Where $ILR_{e,f,q,t}$ = load reductions in year t due to interactive effects for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)
$CES_{e,f,q,t}$ = cumulative regional energy savings for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)
Δheat = the fractional change in heating load
Δcool = the fractional change in cooling load.

These load reductions must be translated into energy savings. To do this, baseline assumptions regarding existing equipment efficiencies and existing equipment market shares are used. First, the load reductions resulting from interactive effects are divided by the baseline existing equipment efficiencies, which yields potential energy savings by equipment type and end use. The potential energy savings assume that each equipment type has 100% of the market, so the actual equipment market shares must then be applied. The market share for each equipment type is multiplied by the potential energy savings to determine the actual energy savings. Equation 2-42 illustrates the energy savings by equipment type and end use calculations:

$$IES_{e,f,q,t} = \frac{ILR_{e,f,q,t}}{e_{e,f,q,t}} * M_{e,f,q,t} \qquad \textit{Equation 2-42}$$

Where $IES_{e,f,q,t}$ = energy savings in year t due to interactive effects for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$ILR_{e,f,q,t}$ = load reductions in year t due to interactive effects for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$e_{e,f,q,t}$ = equipment efficiency in year t for end-use *e*, fuel type *f*, and equipment type *q*

$M_{e,f,q,t}$ = equipment market share in year t for end-use *e*, fuel type *f*, and equipment type *q*.

Derive Final Energy Savings

The lighting energy savings and the space-conditioning energy savings are combined and summed over end uses and equipment to provide the final net energy savings. The final net energy savings are aggregated by building sector, type, vintage, region, and fuel type to determine the total site electric savings, total natural gas savings, and total oil savings.

2.1.4 Other Components

This section addresses calculations made within BESET that occur after the individual energy algorithms described above. Each of the following computations applies not only to BESET-estimated projects but also to projects with savings estimated by NEMS-PNNL or spreadsheets models. For projects estimated by methods other than BESET, site energy savings (electric, gas, and oil), investment, and any non-energy costs are first imported into BESET. These inputs are broken out by building sector, type, vintage, region, and year, as are all final outputs of the calculations described below.

Calculate Primary Energy Savings

For BESET-estimated projects, site energy savings are calculated within the algorithms already discussed above. For other projects, site energy savings are provided to BESET as an input. Total site energy consists of site electric, natural gas, and fuel oil savings. To derive primary electric savings, the exogenous site electricity savings are multiplied by a year-specific electricity conversion factor within BESET (see Appendix C). Primary non-electric savings consists of the sum of natural gas and oil savings. Summation of primary electricity and primary non-electric savings yields the total net primary energy savings. The units for all of these data are TBtu.

Calculate Emissions Reductions and Energy Cost Savings

BESET input data include energy prices and site-energy emission factors, both of which are building sector-, fuel- (electric, gas, and oil), and year-specific (see Appendix C). Emission factors are included for carbon equivalent emissions, sulfur dioxide (SO_2), nitrous oxides (NO_x), volatile organic compounds (VOCs), particulate matter (PM), and carbon monoxide (CO). EERE's official GPRA guidance provides the various factors used (EERE 2002, Appendix B). Factors are multiplied by site energy savings, and prices are multiplied by the respective fuel savings. The resulting energy cost savings are reported in millions of dollars, and the emissions reductions are represented as millions of metric tons (MMton) avoided.

Determine Required Investment and Non-energy Costs

For projects estimated outside of BESET, investment and non-energy costs are provided as an input to BESET. For BESET-estimated projects, investment and non-energy costs are output as part of the process, and their estimation relies on the installed units calculated in the above algorithms. These units are in terms of either million households (residential), or billion square feet (commercial) building sectors. Per-unit equipment costs (dollars per square foot or dollars per household) are multiplied by installed units, as Equation 2-43 shows:

$$I_t = c_t * u_t \qquad \textit{Equation 2-43}$$

where I_t = investment in year t
c_t = per-unit installed cost in year t
u_t = number of units impacted in year t.

Similarly, non-energy costs are calculated as follows:

$$NE_t = ne_t * u_t \qquad \textit{Equation 2-44}$$

where NE_t = non-energy cost in year t
ne_t = per-unit non-energy cost in year t
u_t = number of units impacted in year t.

Each of these calculations is performed for base costs, BT/WIP project costs, and the incremental costs. After necessary conversions, the resulting investment and non-energy costs are reported in millions of dollars.

2.2 General Methodology Using NEMS-PNNL

Many of the projects in BT's Emerging Technologies and Equipment Standards decision units and WIP's Gateway Deployment decision unit target specific types of equipment within a building or standards directed toward using specific equipment. Equipment projects are characterized by new equipment efficiencies and are compared with "baseline" efficiencies to calculate energy savings. To determine the penetration of the BT/WIP-sponsored equipment relative to the more conventional equipment, a modified version of the NEMS model (NEMS-PNNL) employed for EIA's *Annual Energy Outlook 2001* was used.
NEMS-PNNL selects specific technologies to meet the energy services demands by choosing among a discrete set of technologies that are exogenously characterized by commercial availability, capital costs, operating and maintenance costs, efficiencies, and lifetime. NEMS-PNNL is coded to allow several possible assumptions to be used about consumer behavior to model this selection process. For the GPRA effort, the menu of equipment was changed to include relevant BT/WIP-sponsored project equipment, technological innovations, and standards.

The NEMS-PNNL design can accommodate various technology choices. For the GPRA FY 2004 metrics, the NEMS-PNNL data input was adjusted to reflect BT/WIP technology choices. For BT/WIP projects that target efficiency of the building envelope (or shell), specific shell-efficiency indices were read into the model.

The NEMS-PNNL commercial and residential demand modules generate forecasts of energy demand (energy consumption) for the commercial and residential sectors. The commercial demand module generates fuel consumption forecasts for electricity, natural gas, and distillate fuel oil. These forecasts are based on energy prices and macroeconomic variables from the NEMS system, combined with external data sources. The residential model uses energy prices and macroeconomic indicators to generate energy consumption by fuel type and census division in the residential sector. The commercial and residential demand modules are described in the following subsections.

2.2.1 Commercial Demand

This module develops projects of energy consumption by major types of commercial buildings, including assembly, education, food service, food sales, health care, lodging, mercantile and service, office buildings, and warehouses. Commercial energy demand within NEMS-PNNL is calculated in four basic steps:

1. Forecast commercial sector floorspace.
2. Forecast energy services such as space conditioning equipment, lighting, water heating, and refrigeration.
3. Select specific technologies to meet the demand of energy services, which involves modeling consumer behavior and capturing the decision between such equipment as incandescent lights and fluorescent lights.
4. Determine how much energy will be consumed by the equipment chosen to meet the demand for energy services.

The third step is a key element in calculating the estimated energy savings of a given technology promoted by a particular BT/WIP project. Within this step, consumers are assumed to purchase energy-using equipment to meet three types of service demands: services for new buildings, replacement of old equipment that is at the end of its technical life, and replacement of old equipment that is at the end of its economic life (although it still may be technically viable). The NEMS-PNNL commercial model is structured to allow the use of several possible assumptions about consumer behavior to model this decision process. The assumptions are designed to represent empirically the range of economic factors that most influence the consumer's decision and include the following:

- Consumer buys the equipment with the minimum life-cycle cost.
- Consumer buys equipment that uses the same fuel as existing and retiring equipment but minimizes costs across technologies using that fuel.
- Consumer buys (or keeps) the same technology as the existing and retiring equipment but chooses among different efficiency levels based on minimum life-cycle cost.

The model is designed to choose among a discrete set of technologies that are exogenously characterized by commercial availability, capital costs, operating and maintenance costs, efficiencies, and lifetime. For GPRA metrics, the menu of equipment may be altered to include relevant BT/WIP project equipment, technological innovations, and standards. The NEMS-PNNL design can accommodate a changing menu of technology choices, recognizing that changes in energy prices and consumer demand may significantly change the set of relevant technologies that the model user wishes to consider.

2.2.2 Residential Demand

The residential sector demand module includes single-family, multifamily, and mobile home dwellings. Residential energy demand is modeled using a sequence of five steps:

1. Forecast housing stock.
2. Select the specific technologies to meet the demand for each energy service (e.g. furnaces and heat pumps).
3. Forecast appliance stocks that are required by each end-use service.
4. Forecast changes in building-shell integrity; building-shell efficiency in new construction is assumed to improve over the forecast period because of stricter building codes and other efficiency projects and may fluctuate in response to fuel price changes from the base year.
5. Calculate the energy consumed by the equipment chosen to meet the demand for energy services.

As with the commercial model, the GPRA metrics methodology involves modifying the technology performance and cost inputs to reflect the BT/WIP-developed equipment. The technology and equipment selection simulates the behavior of residential consumers based on the relative importance of life-cycle costs, capital costs, and operating costs of competing technologies within a service. Decisions on new and replacement equipment reflect additional factors beyond the traditional life-cycle cost methodology, including space heating fuel choice and previous equipment choices. The technology and equipment selection allocates end-use services based on a defined equipment menu of the various technologies and fuels that compete in the market.

2.2.3 Methodology for Market Transformation-Type Projects

This section discusses the methodological approach to calculating energy savings for projects that attempt to increase sales by modifying consumer behavior. The following projects are characterized in NEMS-PNNL by changes to consumer behavior assumptions:

- Energy Star gas and electric water heaters (in WIP – Gateway Deployment decision unit)
- Energy Star refrigerators (in WIP – Gateway Deployment decision unit)
- Energy Star clothes washers (in WIP – Gateway Deployment decision unit)
- Energy Star room air conditioners (in WIP – Gateway Deployment decision unit)
- Energy Star dishwashers (in WIP – Gateway Deployment decision unit).

The modifications to the NEMS-PNNL input file (RTEKTY) for each appliance with an Energy Star project are described more fully in the project characterizations for Energy Star in Appendix B. That appendix documents the baseline assumptions made by EIA, the changes in the Beta1 coefficients, and the resulting changes in the market shares for the most energy-efficient products. For a few appliances, some changes were made in the baseline assumptions made by EIA. The reasons for these changes are briefly discussed.

The two modeling parameters are labeled by EIA as Beta1 and Beta2. Beta1 is used as multiplicative factor with the initial cost of the appliance, and Beta2 is used to multiply the annual energy cost. The sum of the two products (i.e., Beta1 * initial cost + Beta2 * operating cost) is used in the logit specification to yield market shares for each technology. These coefficients are specific to each equipment type and fuel type. As a rough approximation, the ratio of Beta1/Beta2 can be interpreted as the consumer discount rate for the specific appliance. The Beta1 and Beta2 coefficients are contained with the cost and

efficiency data inputs in the file RTEKTY. In the residential NEMS module, the Beta1 and Beta2 coefficients vary among appliances, as do the resulting discount rates. For example, the implied discount rate for refrigerators is 16%. On the other hand, the discount rate is estimated to be over 80% for electric water heaters.

2.2.4 Methodology for Equipment Projects

NEMS-PNNL was used to estimate the energy savings associated with the products being developed under BT's Appliances and Emerging Technologies project. The modifications to the NEMS-PNNL input files (RTEKTY.txt for residential, KTECH.wk1 for commercial) for each type of equipment in the Appliances and Emerging Technologies project are described in detail in the project characterizations in Appendix A. The appendix documents EIA's baseline assumptions, the cost and performance attributes of the BT-sponsored technologies and the resulting market shares for these most energy-efficient products.

For a few appliances, some changes were made in EIA's baseline assumptions. Where the original *Annual Energy Outlook 2001* input file does not reflect pending standards that are scheduled to take effect during the analysis period, modifications were made to crudely account for these standards.

One issue related to assessing benefits with the NEMS-PNNL model is the appropriate discount rate to use. If the implied discount rate is too high, discouraging most consumers from choosing the technology, then the logit parameters, Beta1 and Beta2, may be modified. Energy Star or other market transformation projects provide impetus for increased market acceptance of selected technologies. Therefore, when appropriate, parameters are modified to decrease the implied discount rate (i.e., encourage consumers to choose this technology earlier) for the technologies targeted by these projects.

The project's energy savings are therefore calculated as the difference between NEMS-PNNL model runs that 1) include the technology assumed in the *Annual Energy Outlook* base case and 2) substitute the lower-cost units assumed to stem from the BT/WIP project.

2.2.5 GPRA Envelope Calculations Using NEMS-PNNL

The general approach for GPRA envelope calculations using NEMS-PNNL was to simulate the effect of an envelope technology using the FEDS model for many different building types, sizes, vintages, and locations. The heating and cooling loads were calculated for each building with and without the envelope technology being evaluated. The changes in the heating and cooling loads were then used to modify the heating and cooling envelope factors in NEMS-PNNL. These factors were input as a vector for each building type and census region; these vectors captured both the thermal impact and the expected market penetration by year. Market penetration estimates were based on input from the DOE project manager or their representatives.

FEDS Modeling

To estimate the national impact of introducing a new envelope technology, the impact of that technology must be accurately captured within the buildings where it is likely to be employed. For each technology, the impact was simulated in 3,960 commercial buildings and 1,188 residential buildings representing all combinations of building type, size, vintage, and location (see Table 2-1).

Aggregating FEDS Results for NEMS-PNNL

Because NEMS-PNNL only models one of each building type in each of the nine census regions, the FEDS results needed to be aggregated for input into NEMS-PNNL.

City Weights. The cities shown in Table 2-1 were selected for the FEDS analysis because the weather is characteristic of the climate in the different portions of the census regions. Because NEMS operates on a census region basis, weighted averages of the FEDS results for individual weather cities were produced to represent the loads within a census region. Table 2-2 shows the weights given to each city for each census region.

Table 2-1. Building Simulation Parameters

Building Type	Building Size (ft^2)	Vintage (Year Built)	Location
Assembly	4000	1940	Denver, Colorado
Education	7500	1953	Detroit, Michigan
Food Sales	17500	1967	Fresno, California
Food Service	37500	1976	Knoxville, Tennessee
Healthcare	75000	1983	Los Angeles, California
Lodging	125000	2000	Minneapolis, Minnesota
Mercantile and Service			Phoenix, Arizona
Office			Providence, Rhode Island
Warehouse			Seattle, Washington
Other Commercial Buildings			Shreveport, Louisiana
Single Family	600		Tampa, Florida
Mobile Home	800		
	1300		
	1800		
	2200		
	3000*		
Multifamily	14309		
	19079		
	31003		
	42927		
	52466		
	71545		
*Single-family and mobile homes are represented by the 600 to 3000 single-family range.			

Table 2-2. Weights Given to Each City for Each Census Region (%)

City	New England	Mid Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
Denver	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.0	2.2
Detroit	0.0	0.0	99.3	60.0	0.0	0.0	0.0	0.0	0.0
Fresno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3
Knoxville	0.0	0.0	0.0	0.0	50.7	67.4	13.4	0.0	0.0
Los Angeles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.2
Minneapolis	0.0	0.0	0.7	40.0	0.0	0.0	0.0	0.0	0.0
Phoenix	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	0.0
Providence	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2
Shreveport	0.0	0.0	0.0	0.0	17.7	32.6	80.6	0.0	0.0
Tampa	0.0	0.0	0.0	0.0	31.6	0.0	6.0	0.0	0.0

Floor Area Weights. The fraction of floor space within each size category for each commercial building type was determined using data from 1995 "Commercial Buildings Energy Consumption Survey"[b] and is shown in Table 2-3.

Table 2-3. Percentage of Floor Space in Each Size Category for Each Commercial Building Type (%)

Building Type	Floor Space Size Category— Range and [Modeled Size] ft²						
	≤5,000 [4,000]	5,001-10,000 [7,500]	10,000-25,000 [17,500]	25,001-50,000 [37,500]	50,001-100,000 [75,000]	>100,000 [125,000]	Total
Assembly	7.9	19.9	23.8	12.3	12.6	23.5	100.0
Education	3.2	5.2	13.5	23.6	22.6	31.8	100.0
Food Sales	36.4	6.4	31.8	19.1	5.1	1.3	100.0
Food Service	40.7	28.8	24.4	5.2	0.6	0.3	100.0
Healthcare	6.5	6.5	10.4	7.5	5.5	63.6	100.0
Lodging	4.1	7.4	20.7	14.2	16.9	36.7	100.0
Mercantile and Service	14.5	17.3	23.1	9.3	10.0	25.7	100.0
Large Office	0.0	0.0	0.0	0.0	27.5	72.5	100.0
Small Office	21.7	18.9	32.7	26.7	0.0	0.0	100.0
Other Buildings	10.8	12.8	19.7	13.0	13.5	30.1	100.0
Warehouse	9.5	11.7	18.0	13.7	13.5	33.5	100.0

Table 2-4 shows the fraction of floor space within each size category for each residential building type (single family, mobile homes, and multifamily). The data for single-family and mobile homes were determined using data from the 1997 "Residential Energy Consumption Survey"[c] and the data for multifamily homes were determined using data from survey and apartment stock data from the National Multi-Housing Council.[d]

[b] Table 9. Where no data were available, expert judgment was used.
[c] Table HC1-4b, single-family, and Table HC1-4b, five or more units.
[d] http://www.nmhc.org/research/default.html.

Table 2-4. Fraction of Floor Space in Each Size Category for Each Residential Type (%)

Building Type	Single-Family Residential Floor Space Size Category— Range and [Modeled Size] ft²					
	≤600 [600]	601-999 [800]	1,000-1,599 [1,300]	1,600-1,999 [1,800]	2,000-2,399 [2,200]	>2,400 [3,000]
Single Family	2.8	14.0	37.0	21.2	11.3	13.7
Mobile Home	15.7	43.8	31.6	7.2	2.2	0.7
Building Type	Multifamily Residential Floor Space Size Category— Range and [Modeled Size] ft²					
	≤14,309 [14,309]	14,310-23,848 [19,079]	23,849-38157 [31,003]	38,158-47,696 [42,927]	47,697-57,236 [52,466]	>57,236 [71, 545]
Multifamily	25.4	49.3	17.9	2.4	0.7	0.2

Vintage Weights. For simplicity, all vintages were given equal weighting.

Market Penetration. The DOE project manager or representative provided market penetration point estimates. For example, the project manager estimated the market penetration to be 15% in 2020 for quick-fill walls in new single-story buildings. Given that 41.8%[e] of commercial buildings are single-story, the resulting market penetration rate is 6.3%. These estimates were then used in the previously developed and documented market penetration model (see Section 3.0, "Diffusion Curves") to estimate the market penetration by year. Pertinent data for the market penetration estimates are provided in the individual project characterizations in Appendix A.

Baseline Assumptions

Consistent with the NEMS-PNNL model, the heating and cooling envelope factors were assumed to be decreasing over time. These changes account for technological improvements over time that would occur without the DOE project. The baseline envelope factors in NEMS-PNNL were modified annually to account for the technological improvements, and the modifiers are calculated using the following equation with 1995 being the base year:

$$BaselineModifier_{new\ buildings} = 0.94\left(\frac{Current\ Year - 1995}{25}\right)$$

Equation 2-45

$$BaselineModifier_{existing\ buildings} = 0.96\left(\frac{Current\ Year - 1995}{25}\right)$$

The project benefits are in addition to the baseline modifier.

[e] 1995 "Commercial Buildings Energy Consumption Survey," Table 9.

Special Considerations

For the electrochromic windows project, 30% of the lighting energy used in commercial buildings is also assumed to be saved (see the project characterization in Appendix A for details). These savings occur at the same rate as the penetration of the electrochromic technology.

Output

The FEDS output for each technology is processed into the following information for direct use by NEMS:

- Census division
- Building type
- Year
- Total heating envelope factor adjustment for new buildings
- Total cooling envelope factor adjustment for new buildings
- Total heating envelope factor adjustment for existing buildings
- Total cooling envelope factor adjustment for existing buildings
- Lighting load adjustment for new buildings
- Lighting load adjustment for existing buildings.

2.3 Spreadsheet Models

Whenever possible, PNNL modeled projects within BESET or NEMS-PNNL to help ensure consistency in baseline inputs and methodology. However, we modeled several projects in spreadsheets because of their unique characteristics. The estimated savings generated by the spreadsheet models are entered by fuel type into "fixed" tables within BESET so that the environmental and energy cost-savings benefits can be calculated using the same data set as the other projects. Detailed documentation on each spreadsheet model is contained in the appropriate project characterization in Appendixes A and B. A summary is presented below.

2.3.1 State Energy Project

This project was modeled based on historical information that provides an estimated level of savings per project dollar. Because neither BESET nor NEMS-PNNL is designed for this type of analysis, the project continues to be modeled in a separate spreadsheet. See Appendix B for a detailed explanation of the inputs for and calculation of the State Energy Project benefits.

2.3.2 Weatherization Assistance Project

This project was modeled based on studies that have provided the project with per-household savings estimates. While these inputs may be able to be translated into load reductions and the project run through BESET, such an effort has not been undertaken. The primary barrier to incorporating this project into BESET is that fuel mix for houses in the target market is significantly different between the BESET baseline and historical Weatherization project data. See Appendix B for a detailed explanation of the inputs for and calculation of the Weatherization Assistance Project benefits.

2.3.3 Information Outreach

The estimates for the FY 2004 request were adopted directly from a study commissioned by BT (Messersmith and Azimi 2000). See Appendix B for a detailed explanation of the inputs for and calculation of the Information Outreach benefits.

2.3.4 Building Codes

Building code activities are spread among three decision units, two in BT and one in WIP. However, because of the interrelationships between the three, savings were estimated for the building codes and standards as a whole. Savings estimates were then allocated among the three primary funding sources:

- Building Codes Training and Assistance (within WIP – Gateway Deployment decision unit)
- Residential Building Codes (within BT – Residential Buildings decision unit)
- Commercial Building Codes (within BT – Commercial Buildings Integration decision unit).

The long-term impact of DOE's assistance to code activities is based largely on data developed for internal use in building codes and standards. DOE provides technical support for states seeking to adopt new energy codes, either based on ASHRAE Standard 90.1, "Energy Standards for Buildings, Except Low-Rise Residential Buildings," or the International Energy Conservation Code (previously the Model Energy Code). Several states have self-developed codes that are not supported by building codes and standards and are not counted in the estimates of project impact. See Appendix A for a summary of the inputs for and calculation of the benefits of Building Codes projects.

2.3.5 Lighting R&D: Lighting Controls

PNNL based the estimates of lighting controls savings on an assumed lighting end-use load reduction, penetration rates, and building stock estimates. Energy savings estimates were developed in a spreadsheet model because BESET and NEMS-PNNL are designed to calculate changes in specific lighting technologies and efficacies; not general lighting load reductions. See Appendix A for a detailed explanation of the inputs for and calculation of the lighting controls benefits.

2.3.6 Space Conditioning and Refrigeration R&D: Commercial Refrigeration

The refrigeration savings estimates were based on a report on end-use consumption produced by PNNL, project goals, and other various data sources (Belzer and Wrench 1997). Energy-savings estimates were developed in a spreadsheet model because commercial refrigeration is a service, not a specific piece of equipment, and therefore cannot be modeled in NEMS-PNNL or BESET. See Appendix A for a detailed explanation of the inputs for and calculation of the commercial refrigeration benefits.

2.3.7 Equipment Standards and Analysis: Distribution Transformers

Distribution transformers are part of the electricity distribution system, not the building system. Therefore, transformers cannot be modeled in either NEMS-PNNL or BESET. Savings estimates for a distribution transformer standard were based on a study by Geller and Nadel (1992). See Appendix A for a detailed explanation of the inputs for and calculation of the distribution transformer benefits.

3.0 Technology Diffusion Models – Application to Selected Energy-Efficient Products for Buildings

Diffusion models represent the principal forecasting method for determining potential market penetration for products that have not yet been introduced into the marketplace. Because this situation generally applies to the long-term forecasting horizon of technology assessment models, a means to credibly represent price and policy effects in diffusion models is a key factor in improving the usefulness of market assessment studies. The basic diffusion models assume that the cumulative market penetration follows a characteristic time path (usually in the form of an S-shaped curve).

The dominant type of diffusion model is most likely the mixed-influence model introduced by Frank Bass (1969). The Bass model incorporates parameters that reflect both external (e.g., mass media communication) and internal influences (e.g., word of mouth). In 1998, PNNL conducted a study for DOE/BT to estimate the Bass specification for ten selected energy-efficient building products available in the marketplace today. The results of this work are instrumental in helping to project the likely market pathways of advanced building technologies under development by DOE/BT. This section summarizes the results of that study.

3.1 Scientific and Technical Approach

PNNL conducted a study examining the historical market penetration for ten energy-efficient products related to the buildings sector. Diffusion models were estimated for each product, based on the specification proposed by Bass (1969). The resulting models are intended to help assess technologies supported by BT. This model development and empirical analysis are designed to generate more credible predictions of the adoption process of important energy-efficiency technologies in the buildings sector.

The basic Bass diffusion model, which is possibly the most widely used specification for analyzing market penetration, assumes that the potential market in which the new technology is penetrating is fixed. In reality, the potential market usually is growing in response to a falling price as the manufacturing process and industry structure behind the new technology evolve. This study develops a simple structural model that incorporates these effects and that can be easily estimated from historical data. Given a suitable conceptual model, its parameters can be estimated from data related to several energy technologies.

Most studies of technology adoption have focused either on defining the market potential of the new technology or on the pace at which the technology is adopted. Models that have integrated both aspects generally have not been subjected to historical validation of their underlying parameters. Therefore, in general, little empirical basis exists to suggest which process — diffusion or expanding market potential due to falling costs—might be more influential in driving the penetration of new technologies.

3.2 Background

A report by the Research Triangle Institute for the Electric Power Research Institute (EPRI) (1991) provides a good overview of market penetration approaches. Although the

report has a slant toward utilities, much of the discussion applies to all types of energy-saving technologies. The EPRI report clearly distinguishes between two aspects of the process for forecasting market penetration: forecasting market potential and forecasting the rate of market penetration. Forecasting market potential can involve several different concepts of potential, including maximum, technical, and economic potential.

The EPRI report states that the factors affecting the rate of market penetration are predominantly different from factors affecting market potential. For example, comparative advantage—often determined by economic cost—strongly affects market potential. However, comparative advantage doesn't appear to have as strong an effect on the rate of market penetration.

In trying to distinguish the key factors affecting potential vs. penetration, EPRI suggests that market potential is predominantly influenced by the following:

- The market population and demographic trends
- The needs of the market: customer perceptions, attitudes, and beliefs
- Feasibility of the product, which depends on functional characteristics of the product and its economic advantages compared with alternatives.

According to EPRI, the rate of market penetration is predominantly influenced by other factors:

1. Marketing effort, such as promotion, advertising, and product positioning
2. Product characteristics, such as complexity, compatibility, trialability, and observability
3. Characteristics of potential adopters, such as decision-making style, innovativeness, and adoption processes
4. Market characteristics, such as macroeconomic conditions, degree of social interaction among potential adopters, and competitive conditions.

Approaches to predicting the diffusion of a new technology generally fall under the category of judgmental methods or model-based methods. Judgmental methods share the common trait that they don't require mathematical models or computations; they rely implicitly on the experience and perceptions of the forecaster. On the other hand, model-based methods use well-specified algorithms to process and analyze data. Therefore, the model-based methods can provide systematic forecasts of market penetration that are reproducible and amenable to being incorporated into broader integrated models.

Model-based methods can be divided into two major categories: extrapolation models and causal models. Extrapolation methods include the following: 1) naive diffusion process models, 2) moving average, 3) exponential smoothing, 4) Census Bureau X-11, 5) Box-Jenkins, and 6) Multivariate Time Series.

Of the extrapolation methods, the diffusion models represent the principal method for dealing with products that have not yet been introduced. Because this situation generally applies to long-range models, the discussion will be restricted to these models.

Diffusion models assume that the cumulative market penetration follows a characteristic time path (usually in the form of an S-shaped curve). An apt analogy is the spread of contagious disease in a fixed population. Once begun, growth of the disease in the number of infected individuals may follow a stable, predictable path. The time path of the infection

in the population depends on the probability of spontaneous infection, the share of infected individuals, and probability of uninfected individuals interacting with individuals already infected. The notion underlying penetration rate models is that information about the new technology—sufficient to induce its adoption—is similar to an infectious disease (although with a much more positive connotation). This model provides the rationale behind the S-shaped ("logistic") penetration curves that are often observed.

3.3 Bass Diffusion Model

Perhaps the dominant type of diffusion model is the mixed-influence model introduced by Bass in the late 1960s. This two-parameter model incorporates parameters that reflect both external and internal influences. The external influence (corresponding to the "spontaneous" infection mentioned above) is exemplified by mass media communication, size of sales force, or other structured channels of information. Spontaneous refers to the adopter not being influenced by previous adopters but by advertising or some other "external change-agent."

In contrast, the internal influence is intended to capture interpersonal communication or word of mouth (i.e., the contagious aspect of the disease analogy above). This also has been termed the "imitative effect"; the decision to adopt is made only after being influenced by prior adopters. The basic specification of the Bass model is as follows:

$$dN(t)/dt = [p + q/M\ N(t)]\ [M - N(t)] \qquad \textit{Equation 3-1}$$

where
- $N(t)$ = cumulative number of adoptions at time t
- M = market potential, a constant
- p = the coefficient of innovation or external influence
- q = the coefficient of imitation or internal influence.

Equation 3-1 states that the rate of change in the cumulative number of adopters (dN(t)/dt) is proportional to the difference between the market potential M and the number of previous adopters. The proportionality factor [p + q/M N(t)] can be interpreted as the probability of adoption at time *t*. This probability is composed of two components: p is interpreted as the probability of spontaneous adoption. The term [q/M N(t)] relates to the probability that adoption will be chosen based on the influence of previous adopters. This probability grows as the number of adopters increases.

To simplify the presentation, Equation 3-1 can be reoriented in terms of the fraction of the market *(F)* that is being penetrated rather than the absolute number of adopters. In this case, the market potential can be defined as 1.0. This simplified expression in Equation 3-2 now relates to the change in relative cumulative adoptions:

$$dF(t)/dt = [p + qF(t)]\ [1 - F(t)] \qquad \textit{Equation 3-2}$$

The number of cumulative adoptions at any time, *F(t)*, can be solved by specifying an initial condition that the number of adopters at $t = 0$ is 0. This solution is as follows:

$$F(t) = \frac{1 - \exp(-(p+q)t)}{1 + (q/p)\exp(-(p+q)t)} \qquad \textit{Equation 3-3}$$

The basic diffusion models therefore separate the issue of market penetration rate from market potential. That is why the model in Equation 3-3 can be compared across technologies—the percentage change in the total penetration does not depend on the size of the market but only on the parameters *p* and *q*. This overcomes the limiting assumption mentioned above that the market segments, in unit terms, are fixed through time.

3.4 Estimation Issues

Issues related to the appropriate estimation procedures for the Bass diffusion model spawned a considerable literature. At least four estimation procedures were proposed by various researchers: 1) ordinary least squares (Bass 1969), 2) maximum likelihood estimators (Schmittlein and Mahajan 1982), 3) nonlinear least squares (Srinivasan and Mason 1986) and Jain and Rao (1989), and 4) algebraic estimation (Mahajan and Sharma 1986).

Mahajan, Mason, and Srinivasan (1986) performed a comparative study of estimation procedures using penetration data for seven products. They concluded that the maximum likelihood and nonlinear least squares procedures provided the best predictions of the four procedures considered. Between those two procedures, nonlinear least squares provided slightly better predictive performance and more valid estimates of the standard errors for the parameter estimates.

As preliminary analysis, PNNL looked at three variants of nonlinear least squares model. For the first two variants, the focus is on the number of adopters *(X)* in each period. Taking the differences of Equation 3-3 above and including a separate parameter reflect the total number of adopters (m) results in the following for the first variant:

$$X(i) = \frac{m\left(1-\exp(-(p+q)t_i)\right)}{1+(q/p)\bullet\exp(-(p+q)t_i))} - \frac{m\left(1-\exp(-(p+q)t_{i-1})\right)}{1+(q/p)\bullet\exp(-(p+q)t_{i-1}))} + u_i \qquad \textit{Equation 3-4}$$

Jain and Rao (1989) suggest that the formulation in Equation 3-4 gives the *ex ante* value for X(i) and does not use the *ex post* information on X(1), X(2), …, X(I-1). In the Bass model, the probability that an individual who has not purchased the product up to period t_{i-1} is given by $[F(t_i) - F(t_{i-1})]/((1 - F(t_{i-1})]$. Thus, the number of adopters in the *i*th time interval is as follows:

$$X_i = (m - N(t_{i-1}))\left(\frac{F(t_i)-F(t_{i-1})}{1-F(t_{i-1})}\right) + v_i \qquad \textit{Equation 3-5}$$

where $N(t_{i-1})$ is the cumulative number of adopters up to time t_{i-1}, v_i is the error term, and cumulative distribution function is given by Equation 3-3. This *ex post* estimation procedure proposed by Jain and Rao uses the actual number of cumulative adoptions in the estimation, compared with the *predicted* number in Equation 3-4. Therefore, it is termed the *ex post* estimation in contrast to the *ex ante* estimation.

Mahajan, Mason, and Srinivasan (1986) also point out the possibility of estimating the diffusion curve in level rather than differences form (e.g., cumulative sales rather than annual sales). Thus, the cumulative number of adopters is the dependent variable and the specification becomes the following:

$$N(t_i) = mF(t) = \frac{m(1-\exp(-(p+q)t))}{1+q/p \bullet \exp(-(p+q)t)} + w_i \qquad \textit{Equation 3-6}$$

As Mahajan, Mason, and Srinivasan (1986) indicate, the errors in Equation 3-6 are likely to be heteroscedastic (i.e., error variance increasing with i) and autocorrelated. Nevertheless, this formulation is somewhat more stable than the differences form and sometimes yields more plausible estimates.

3.5 Results

The results of estimating the Bass (1969) diffusion model for ten energy-related technologies are described below. The technologies were placed into four separate categories: 1) lighting, 2) HVAC and refrigeration (HVAC/R), 3) envelope, and 4) other. Table 3-1 summarizes the technologies for which Bass diffusion models were estimated.

Table 3-1. Summaries of Technologies Analyzed

Technology	Start Year	End Year	Market Definition
Lighting			
Electronic Ballast	1986	1997	Corrected Power-Factor Ballasts
Compact Fluorescent	1986	1994	Incandescent, 15-150 Watt
T-8 Lamps	1986	1994	Fluorescent lamps, >30 Watt
HVAC and Refrigeration			
Electric Heat Pump	1970	1995	Residential Furnaces
Flame Retention Burner	1975	1987	All Oil Burners
Condensing Gas Furnace	1982	1997	Gas Furnaces
Advanced Compressor	1982	1995	No. of Supermarkets
Room Air Conditioners	1949	1961	No. of Households
Envelope Technologies			
Low-E Window	1983	1996	Residential Windows
Other			
DOE-2 Bldg Model[f]	1984	1994	Commercial Buildings Designed

In most of the cases, the technology was not assumed to ultimately capture all of the market, as defined in the third column of the table. The maximum market potential was determined judgmentally, on the basis of inspection of the data or from other sources.

Table 3-2 presents the results of the estimation work. The parameter sets labeled in bold are those judged as the most preferred, based on the reasonableness of the estimates and statistical significance. While estimates were developed based on both annual adoptions and cumulative adoptions, at this point, estimates based on annual adoptions have been

[f] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact.

used. The annual adoption rates are expressed as a fraction of the total potential market and the maximum fraction of the total market potential is expressed exogenously. The first and third groups of estimates reflect an effort to allow the data to suggest the maximum market potential (m rather than m*).

Examination of the estimated coefficients indicates that the estimates of the external influence parameter are much more variable than those for the internal influence parameter. One of the lowest values of the internal influence coefficient is found for CFLs; this coefficient reflects the lamps extremely slow initial penetration into the market. In addition to the lamp's high initial price, Haddad (1994) suggests that industrial organization, retail incentives, and social convention are additional reasons for the atypically slow adoption of this technology. On the other extreme is the flame retention oil burner, whose adoption was accelerated by the increase in oil prices during the Iranian revolution in the late 1970s. In spite of these extremes, the simple average internal influence coefficient of 0.38 is the same as the average for 213 technologies as reported by Sultan, Farley, and Lehmann (1990). In that study, the average external influence was 0.03 compared with an average 0.018 for the ten energy-related technologies.

Table 3-2. Diffusion Curve Parameter Results

Product	Annual Sales						Cumulative Sales					
	p	q	m	p	q	m*	p	q	m	p	q	m*
Electronic Ballasts	0.0054 (0.6)	0.6489 (2.5)	0.4815 (3.4)	**0.0138** (1.1)	**0.3729** (3.3)	**0.6**	0.0037 (2.1)	0.7006 7.3)	0.4627 (19.5)	0.0092 (3.3)	439 9.3)	0.6
Compact Fluorescent				**0.0075**	**0.071**	**0.50**						
T-8 Lamps				**0.0041**	**0.326**	**0.80**						
Electric Heat Pump				**0.0118**	**0.459**	**0.23**	0.0054 (1.6)	0.6228 5.9)	0.2169 (43.9)	0.0112 (2.2)	0.4588 (6.3)	0.23
Flame Retention Burner				**0.0039**	**0.655**	**1.0**	<0.001 (0.3)	1.774 (3.7)	0.8143 (23.9)	0.0040 (1.1)	0.655 (4.6)	1.0
Condensing Gas Furnace				**0.070** (1.8)	**0.071** (0.8)	**0.3**	0.0782 (3.6)	0.2082 (1.8)	0.238 (14.7)	0.0881 (6.1)	0.0240 (0.6)	0.3
Room Air Conditioners				**0.0072**	**0.423**	**0.33**						
Advanced Compressors	.0232 (9.6)	0.2788 (11.3)	0.9514 (21.3)	**0.0247** (11.2)	**0.2483** (22.1)	**1.0**	0.0242 (31.4)	0.2633 (20.5)	0.9801 (39.8)			
Low-E Windows	0.0562 (8.2)	0.2936 (7.3)	0.3663 (18.3)	**0.0577** (9.6)	**0.2729** (14.3)	**0.37**				0.0565 (25.0)	0.2819 (27.3)	0.37
DOE-2 Building Model	0.00001 (0.5)	1.18 (4.8)	0.279 (6.4)	**0.0005**	**0.656**	**0.50**						

p represents the coefficient of innovation (external influence)
q represents the coefficient of imitation (internal influence)
m is the maximum market potential suggested by the data
m* is an assumed value taken from graphical output
The first and third groups of estimates reflect the results when all three parameters (p, q, and m) are estimated based on the data.
The second and fourth groups of estimates reflect the results when two parameters (p and q) are estimated, with m (as m*) set based on graphical output
Values in parentheses are t-values, where available.

3.5.1 Lighting Technologies

As Table 3-1 outlines, the generic lighting diffusion curve is based on the market penetration of the electronic ballast, compact fluorescent, and T-8 lamp technologies. Tables 3-3 through 3-5 and Figures 3-1 through 3-3 detail the penetration of these technologies and chart the predicted penetration rates. To develop a generic lighting curve, the three lighting technology curves were normalized by setting m* (the maximum market potential) to 1.0. By plotting the three curves using the normalized market potential, a generic curve was specified by visual determination. The resulting parameters for the generic lighting curve are 0.005 (external, or p) and 0.25 (internal, or q). Figure 3-4 charts the diffusion curves for the three technologies and the generic lighting curve.

Table 3-3. Ballast Shipments and Penetration of Electronic Ballasts

Year	Corrected Power-Factor Type (magnetic) (million)	Electronic Type (million)	Total Ballast Shipments (million)	Penetration of Electronic type (fraction)
1986	52.04	0.43	52.47	0.008
1987	54.75	0.65	55.40	0.012
1988	56.80	1.06	57.86	0.018
1989	58.27	1.43	59.70	0.024
1990	55.81	3.00	58.81	0.051
1991	55.47	8.34	63.81	0.131
1992	55.38	13.29	68.67	0.194
1993	54.79	24.49	79.28	0.309
1994	55.99	24.61	80.60	0.305
1995	47.65	32.90	80.55	0.408
1996	42.84	30.34	73.18	0.415
1997	42.89	36.54	79.43	0.460
1998	42.58	39.84	82.42	0.483
1999	41.44	41.63	83.07	0.501
2000	37.54	49.32	86.86	0.568
Source: Bureau of the Census, Current Industrial Reports [MQ36C(97)-5; MQ335C (01)-5.				

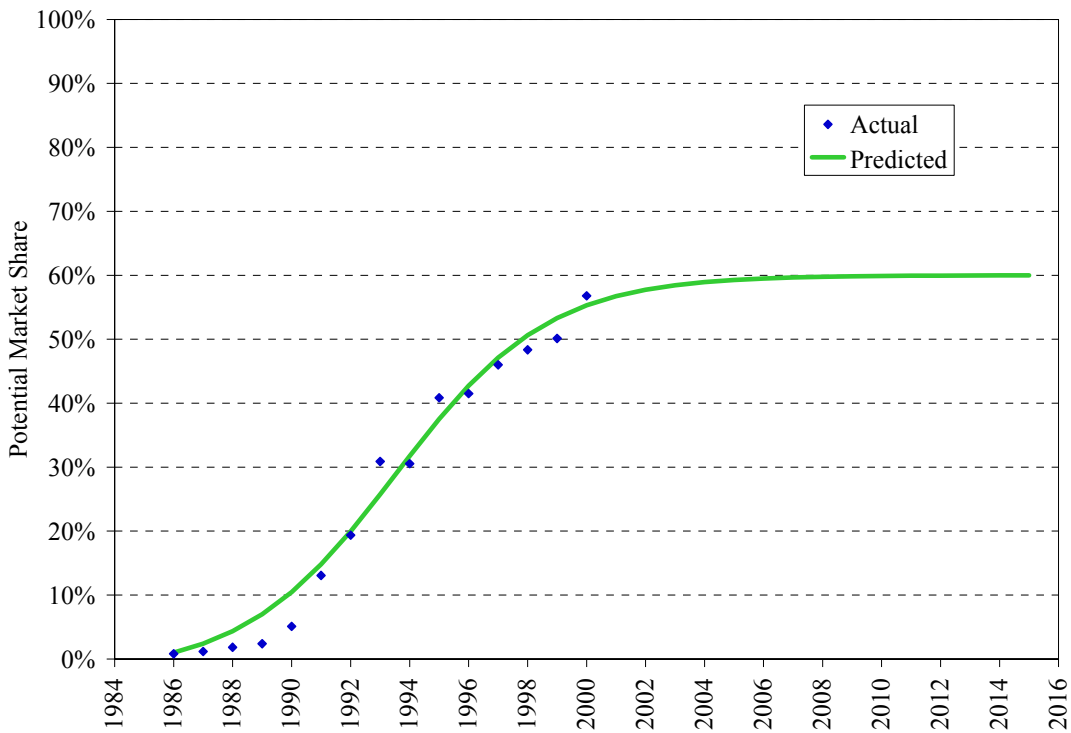

Figure 3-1. Actual and Predicted Penetration Rates: Electronic Ballasts

Table 3-4. Total Fluorescent Tube and T-8 Tube Shipments

Year	Conventional Fluorescent (1)			Linear T-8 (million)	Data Source for T-8
	Low-Power (million)(2)	High-Power (million)	Total (million)(3)		
1985	45	255	300	0	estimate
1986	45	270	315	0.5	estimate
1987	45.7	287	332.7	1	estimate
1988	50	300	350	2	EPRI (4)
1989	55	315	370	3.1	EPRI
1990	62	332.8	394.8	5.7	EPRI
1991	69.3	353.1	422.4	15	estimate
1992	70.3	367.4	437.7	27.7	CIR (5)
1993	71.5	389.9	461.4	43.8	CIR
1994	78.4	399.7	478.1	56.1	CIR

(1) "Conventional Fluorescent" corresponds to the Census Bureau's category of "Other Fluorsecent Lamps"; excludes slimline, circular, and high-output 800 milliamp or more. Includes T-8 Lamps.

(2) Low-power is defined as 40 watts or less prior to 1992, 30 watts from 1992 through 1994. No adjustment was made to achieve definitional consistency.

(3) Values for conventional fluorescent are estimated for 1985, 1986, 1988 and 1989.

(4) EPRI 1992.

(5) CIR: Current Industrial Report, MQ36B.

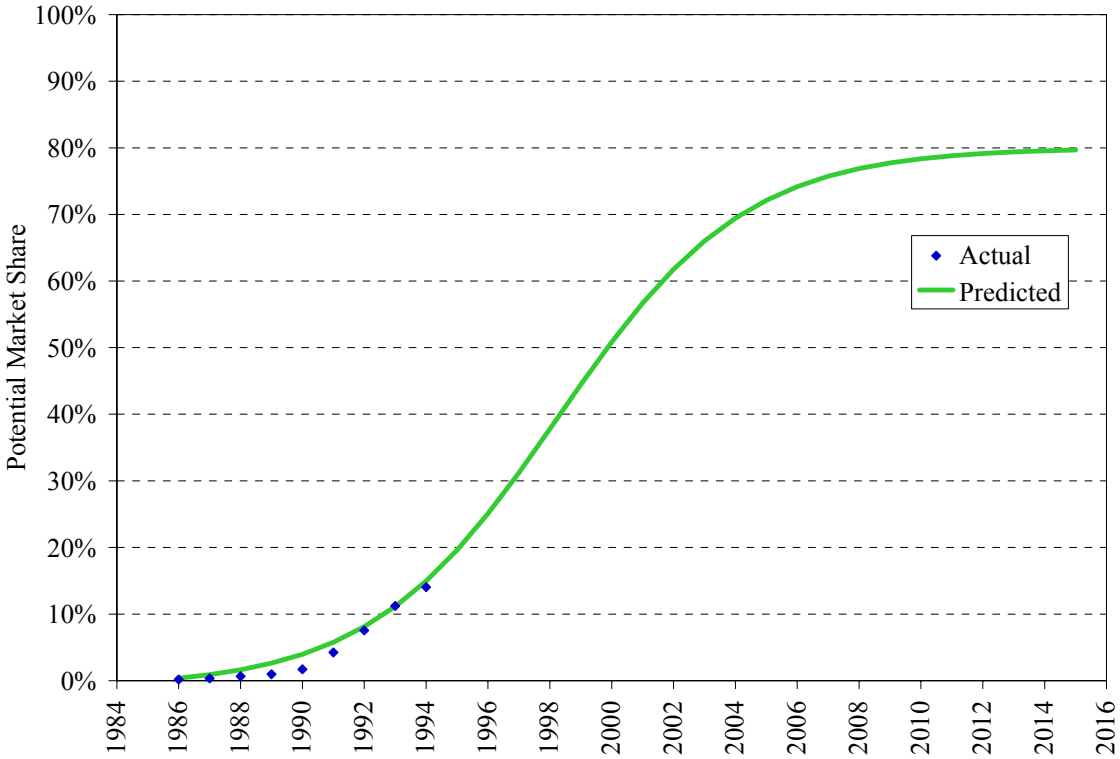

Figure 3-2. Actual and Predicted Penetration Rates: T-8 Lamps

Table 3-5. Shipments and Penetration of CFLs

Year	Incandes. 15-150 watt (million)	CFLs (million)	Total (million)	Market Penetration	Data Sources	
					Incandes.	CFL
1986	800.0	2.0	802.0	0.0025	estimate	estimate
1987	800.0	4.0	804.0	0.0050	estimate	estimate
1988	800.0	9.9	809.9	0.0122	estimate	EPRI
1989	810.7	11.6	822.3	0.0141	CIR*	EPRI
1990	798.6	16.7	815.3	0.0205	CIR	EPRI
1991	783.0	25.2	808.2	0.0312	CIR	estimate
1992	795.5	30.4	825.9	0.0368	CIR	CIR
1993	847.1	33.4	880.5	0.0379	CIR	CIR
1994	818.8	35.8	854.6	0.0419	CIR	CIR

Source: EPRI 1992.
*CIR: Current Industrial Reports, Bureau of the Census, MQ36B, various issues.

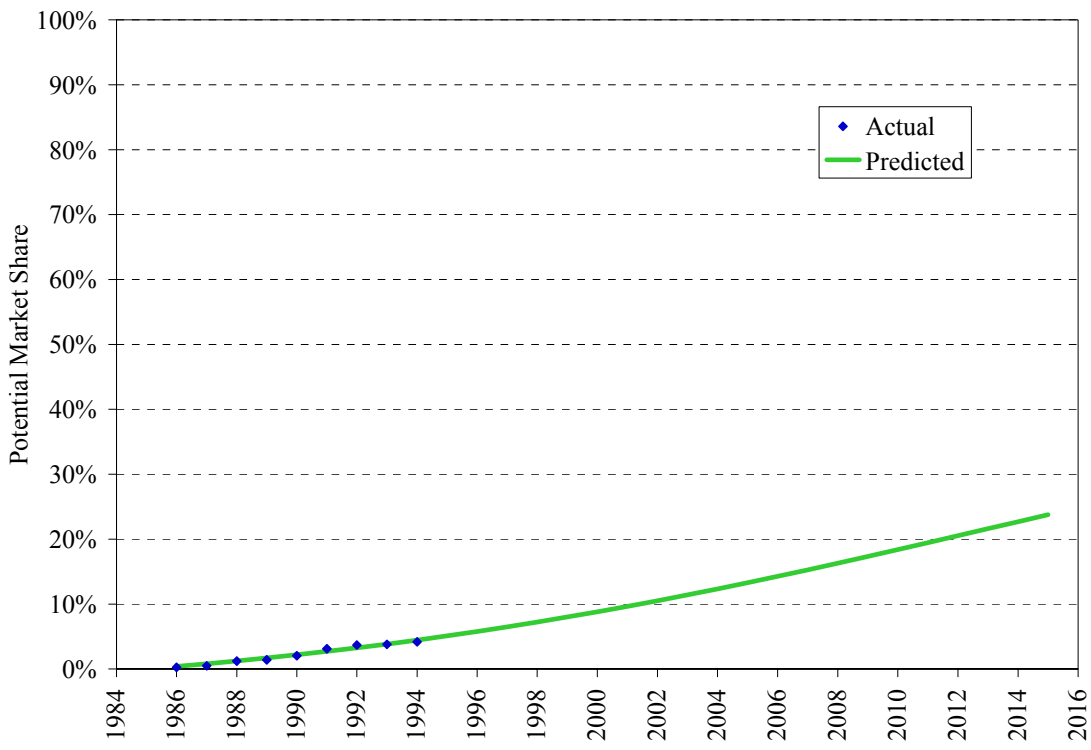

Figure 3-3. Actual and Predicted Penetration Rates: CFLs

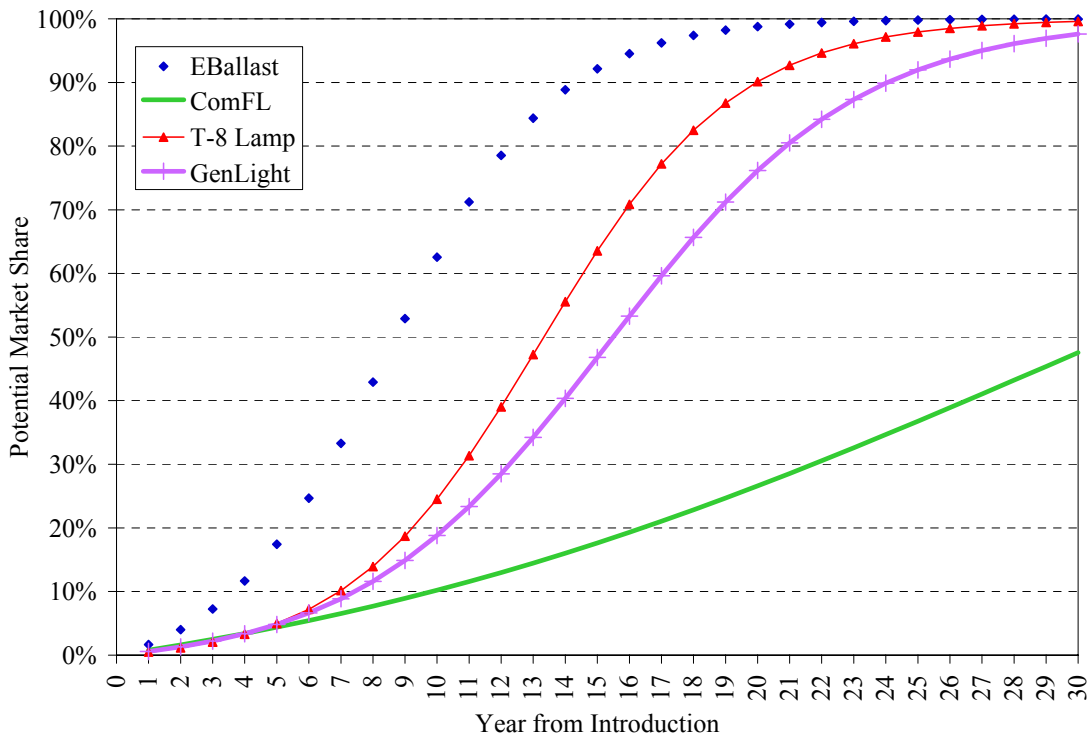

Figure 3-4. Generic Lighting Diffusion Curve Compared With Other Lighting Technology Curves (Normalized to m* = 1.0)

3.5.2 HVAC Technologies

As Table 3-1 outlines, the generic HVAC diffusion curve is based on the market penetration of the electric heat pump, flame retention burner, condensing gas furnace, and room air conditioners technologies. Tables 3-6 through 3-9 and Figures 3-5 through 3-8 detail the penetration of these technologies and the predicted penetration rates. To develop a generic HVAC curve, the four HVAC technology curves were normalized by setting m* (the maximum market potential) to 1.0. By plotting the four curves using the normalized market potential, a generic curve was specified by visual determination. The resulting parameters for the generic HVAC curve are 0.02 (external, or p) and 0.3 (internal, or q). Figure 3-9 charts the diffusion curves for the four technologies and the generic HVAC curve.

Table 3-6. Advanced Electric Heat Pump Shipments and Penetration

Year	Gas Furnaces (thousands)	Electric Furnaces (thousands)	Split System Heat Pumps (thousands)	Total (thousands)	HP Market Penetration (fraction)
1970	1471.2	105.3	33.6	1610.1	0.021
1971	1795.2	193.8	26.6	2015.6	0.013
1972	2066.2	288.5	32.3	2387.0	0.014
1973	1719.5	370.2	43.9	2133.6	0.021
1974	1476.3	406.8	56.6	1939.7	0.029
1975	1185.8	252.3	92.8	1530.9	0.061
1976	1544.4	338.9	202.0	2085.3	0.097
1977	1508.1	283.6	356.8	2148.5	0.166
1978	1636.1	360.0	420.8	2416.9	0.174
1979	1862.6	360.0	407.6	2630.2	0.155
1980	1445.7	360.0	323.4	2129.1	0.152
1981	1416.7	360.0	390.4	2167.1	0.180
1982	1155.6	300.0	300.9	1756.5	0.171
1983	1661.8	360.0	509.6	2531.4	0.201
1984	1849.2	360.0	603.1	2812.3	0.214
1985	1822.3	370.0	665.2	2857.5	0.233
1986	2104.8	382.6	728.3	3215.7	0.226
1987	2072.9	375.1	754.6	3202.6	0.236
1988	2092.2	293.1	680.9	3066.2	0.222
1989	2162.2	298.2	690.0	3150.4	0.219
1990	1950.5	280.0	667.4	2897.9	0.230
1991	2056.7	245.2	637.1	2939.0	0.217
1992	2106.9	290.2	670.0	3067.1	0.218
1993	2584.6	348.5	747.5	3680.6	0.203
1994	2696.8	400.8	857.6	3955.2	0.217
1995	2601.0	402.0	866.6	3869.6	0.224

Sources: For gas furnaces the source is the Census of Manufactures, 1972 and 1977; PNNL estimates are for the intervening years; and the Gas Appliance Manufacturers Association (GAMA) is for years 1986-1995.

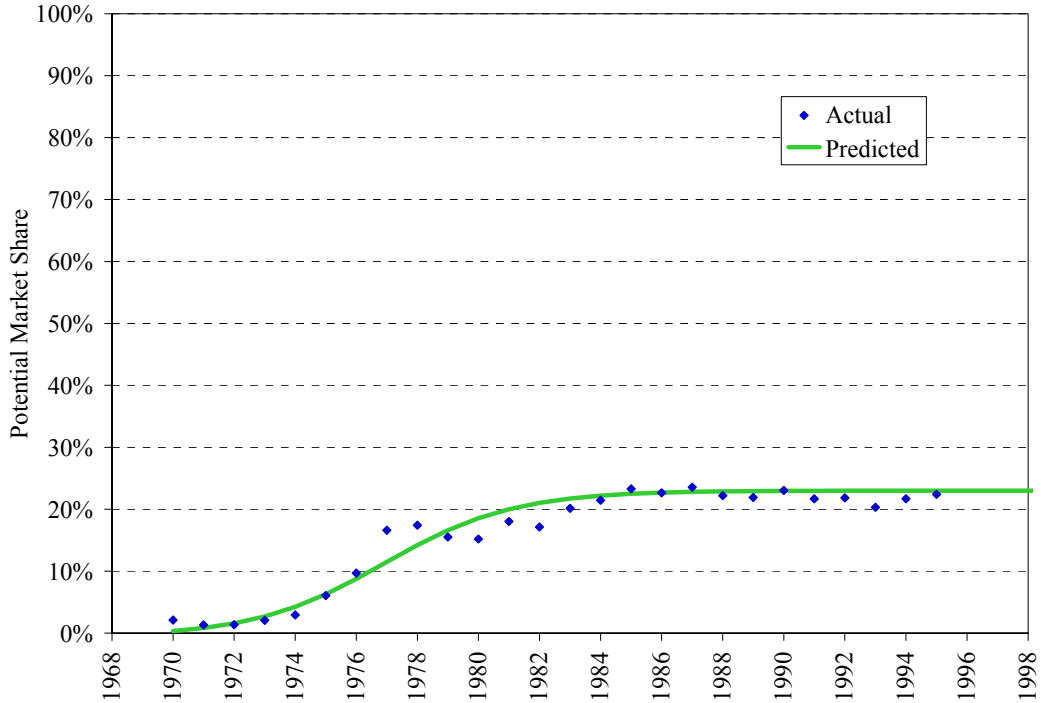

Figure 3-5. Actual and Predicted Market Penetration: Electric Heat Pumps

Table 3-7. Sales and Market Penetration of Flame Retention Head Oil Burners (FRHOBs)

	Annual Oil Burner Sales(1) (thousand)	Cumulative FRHOB Sales(2) (thousand)	Annual FRHOB Sales(3) (thousand)	FRHOB Market Share(4) (fraction)
1975	750	20	20	0.027
1976	750	50	30	0.040
1977	749	70	20	0.027
1978	777	100	30	0.039
1979	735	125	25	0.034
1980	585	250	125	0.214
1981	606	400	150	0.248
1982	522	800	400	0.766
1983	512	1200	400	0.781
1984	510	1600	400	0.784
1985	536	2000	400	0.746
1986	555	2450	450	0.811
1987	577	2950	500	0.867

(1) Annual oil burner sales data from 1977-1987 were obtained through a telephone interview with Don Farrell, using data files maintained by *Fuel Oil and Oil Heat Magazine*. Data for 1975 and 1976 are PNNL estimates.
(2) Cumulative sales for FRHOBs were obtained from ORNL report by Brown et al. (1989), Figure 4.3, p. 55.
(3) Annual FRHOB sales data were estimated as the difference in cumulative sales in Column
(4) Market share of FRHOB is the ratio of FRHOB sales over total burner sales.

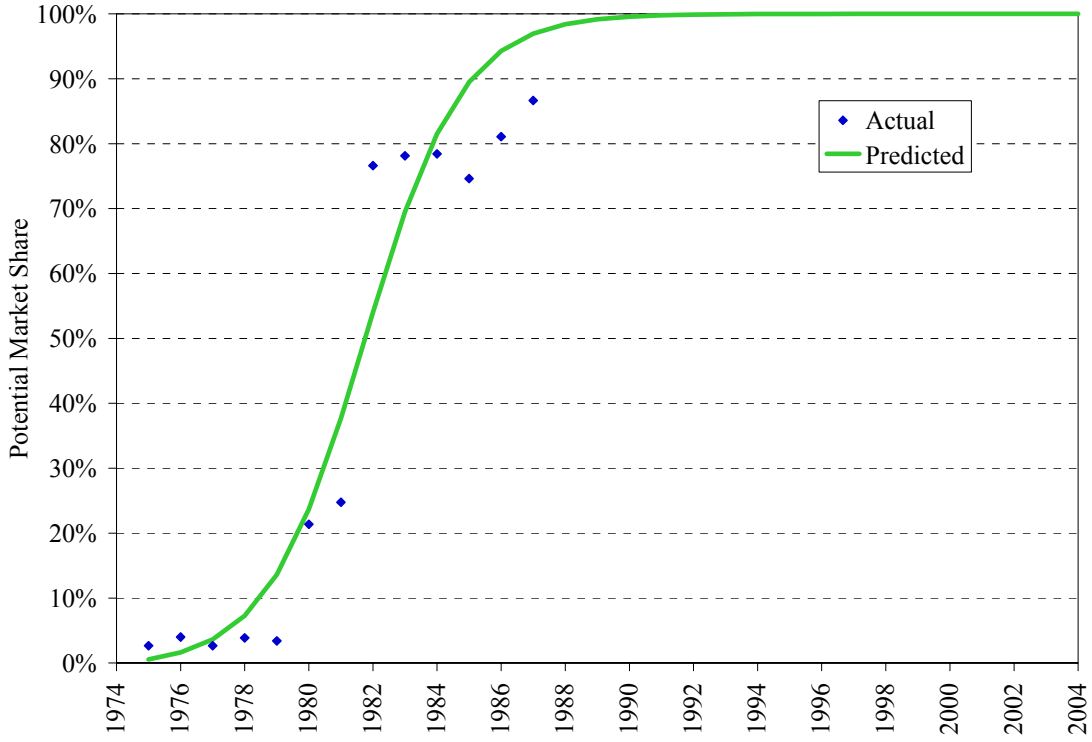

Figure 3-6. Actual and Predicted Market Penetration Rates: Flame Retention Oil Burners

Table 3-8. Market Penetration of High Efficiency Gas Furnaces

Year	Market Share	Source
1981	0.005	PNNL Estimate
1982	0.010	PNNL Estimate
1983	0.040	PNNL Estimate
1984	0.111	GAMA
1985	0.123	GAMA
1986	0.158	GAMA
1987	0.160	PNNL Estimate
1988	0.165	PNNL Estimate
1989	0.170	PNNL Estimate
1990	0.175	GAMA
1991	0.205	GAMA
1992	0.210	PNNL Estimate
1993	0.210	PNNL Estimate
1994	0.214	GAMA
1995	0.223	GAMA
1996	0.235	GAMA
1997	0.253	GAMA
1998	0.240	PNNL Estimate
1999	0.233	GAMA
2000	0.236	GAMA
2001	0.279	GAMA

Note: For 1984-1987, the fraction relates to annual fuel utilization efficiency (AFUE) of 86% and greater. For subsequent periods, the fraction relates to furnaces with AFUE of 86% and greater. Because of some changes in the AFUE testing procedures, these fractions are roughly comparable.

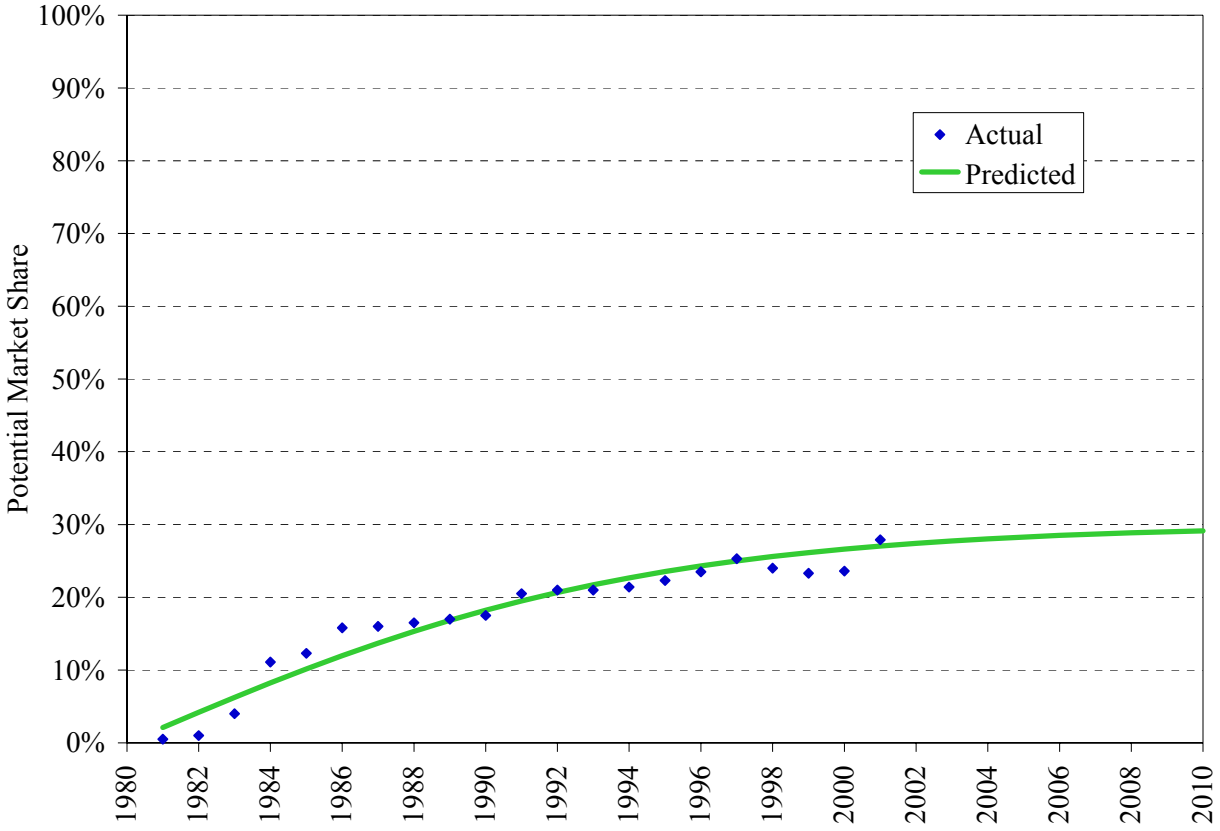

Figure 3-7. Actual and Predicted Market Penetration for Condensing Gas Furnaces

Table 3-9. Room Air Conditioner Sales

Year	Sales (thousands)
1949	96
1950	195
1951	238
1952	380
1953	1045
1954	1230
1955	1267
1956	1828
1957	1586
1958	1673
1959	1800
1960	1580
1961	1500
Source: Mahajan, Mason, and Srinivasan (1986).	

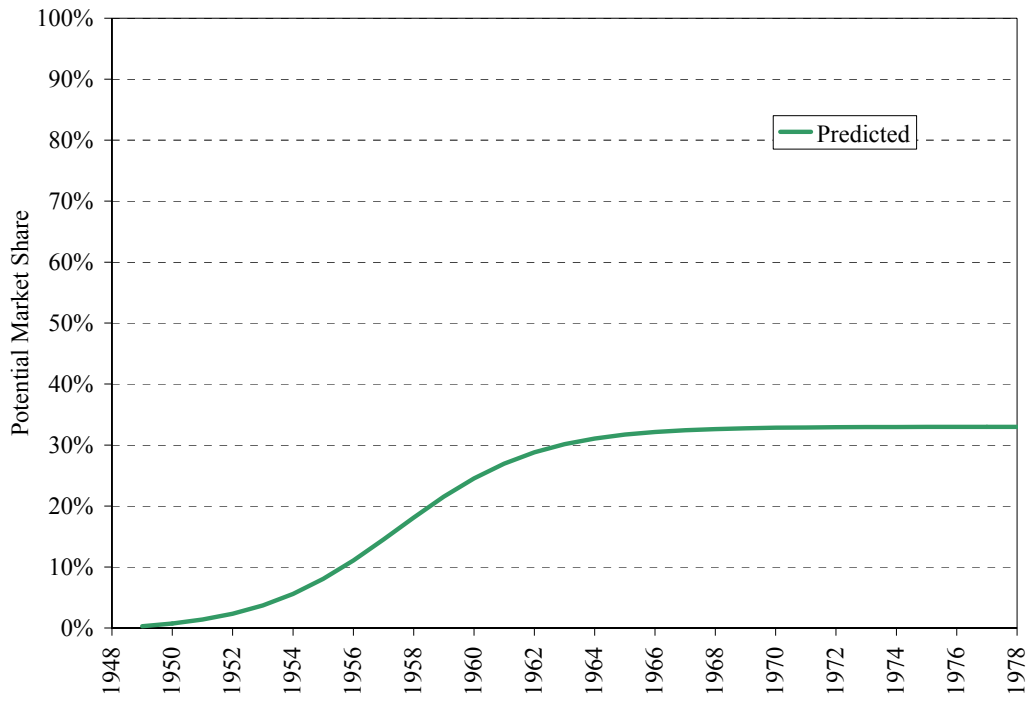

Figure 3-8. Predicted Market Penetration of Room Air Conditioners

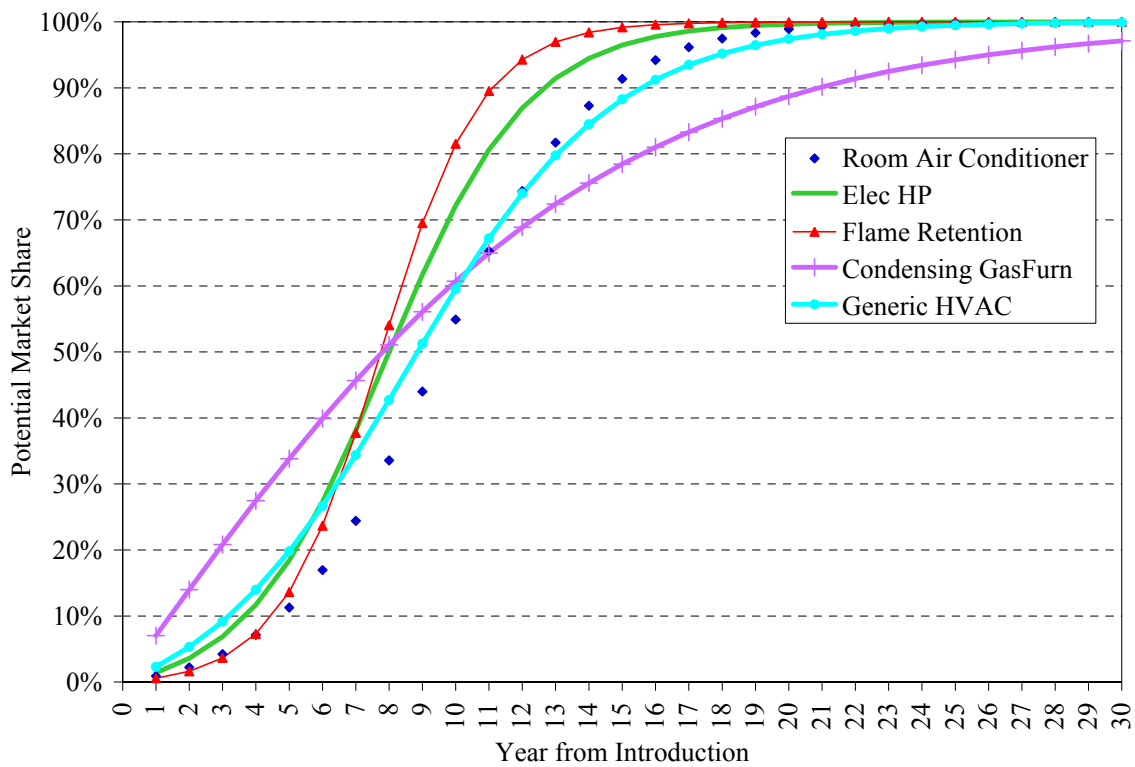

Figure 3-9. Generic HVAC Diffusion Curve Compared With Other HVAC Technology Curves (Normalized to m* = 1.0)

3.5.3 Envelope and Other Technologies

Three other technologies were also studied and form the basis for the generic envelope and other technologies diffusion curve. The generic envelope/other diffusion curve is based on the market penetration of the advanced compressor, low-E window, and DOE-2 technologies.[g] Tables 3-10 through 3-12 and Figures 3-10 through 3-12 detail the penetration of these technologies and chart the predicted penetration rates. To develop a generic envelope/other curve, the three technology curves were normalized by setting m* (the maximum market potential) to 1.0. By plotting the three curves using the normalized market potential, a generic curve was specified by visual determination. The resulting parameters for the generic envelope/other curve are 0.01 (external, or p) and 0.3 (internal, or q). Figure 3-13 charts the diffusion curves for the three technologies and the generic Envelope/Other curve.

Table 3-10. Market Penetration of High-Efficiency Refrigerator Compressors for Supermarkets

Year	Market Penetration (fraction)
1982	0.03
1983	0.06
1984	0.11
1985	0.16
1986	0.21
1987	0.27
1988	0.34
1989	0.41
1990	0.50
1991	0.58
1992	0.65
1993	0.71
1994	0.76
1995	0.80
Source: Geller and McGaraghan 1995, Figure 3.	

[g] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact. The inclusion of the normalized DOE-2 curve into the development of the generic envelope/other curve does cause the generic curve to be less steep than if it were to be fit between the Advanced Compressor and Low-E window curves.

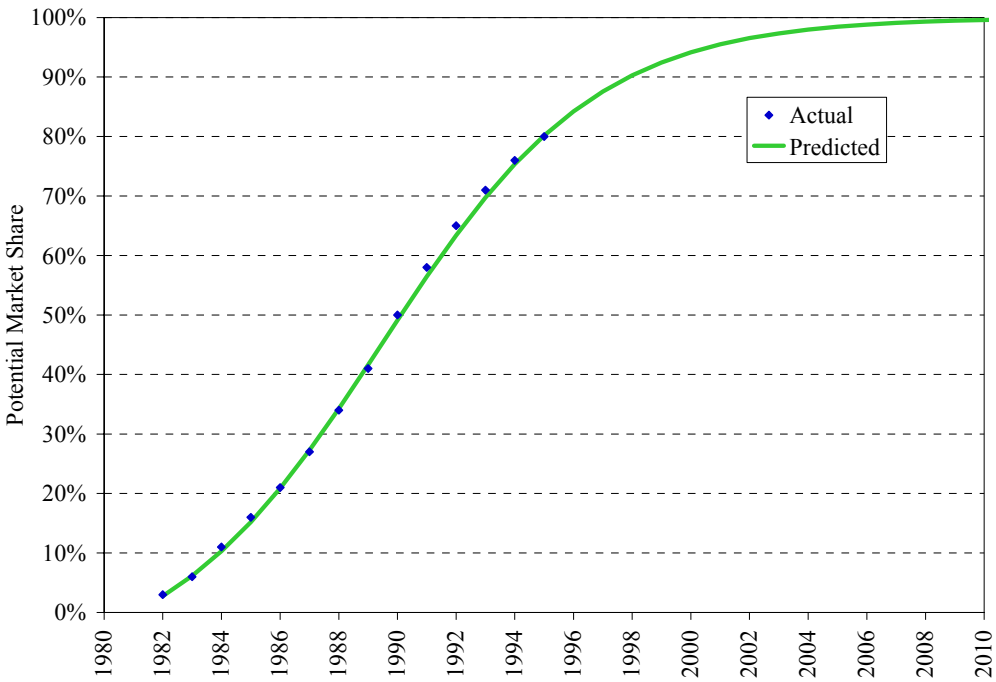

Figure 3-10. Actual and Predicted Market Penetration Rates: Advanced Refrigeration Compressors for Supermarkets

Table 3-11. Market Penetration of Low-E Residential Windows

Year	Market Penetration (fraction)	Source
1983	0.01	PNNL Estimate(1)
1984	0.02	PNNL Estimate(1)
1985	0.05	PNNL Estimate(1)
1986	0.12	ACEEE(2)
1987	0.16	PNNL Estimate(3)
1988	0.20	PNNL Estimate(3)
1989	0.23	PNNL Estimate(3)
1990	0.26	PNNL Estimate(3)
1991	0.28	AAMA(4)
1992	0.30	PNNL Estimate
1993	0.32	AAMA(4)
1994	0.34	PNNL Estimate
1995	0.35	AAMA(4)
1996	0.35	LBNL(5)

(1) Accelerating penetration consistent with 12% share in ACEEE 1996.
(2) Geller and McGaraghan 1996, Figure 1.
(3) Interpolated in a manner to show declining rates of increase.
(4) Study of U.S. Market for Windows and Doors, American Architectural Manufacturers Association (AAMA), 1996.
(5) Personal communication with D. Arasteh, LBNL, on June 11, 1998.

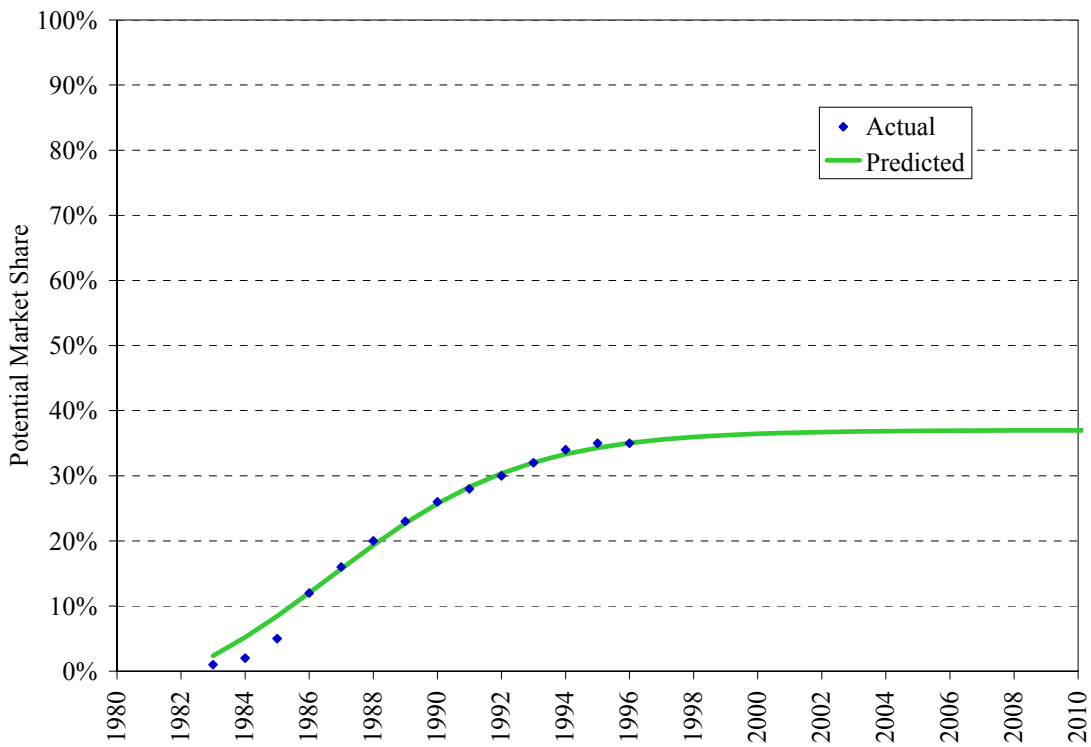

Figure 3-11. Actual and Predicted Market Penetration Rates: Residential Low-E Windows

Table 3-12. Market Penetration of DOE-2 Used as a Design Tool [h]

Year	Market Penetration (fraction)
1984	0.006
1985	0.013
1986	0.019
1987	0.025
1988	0.031
1989	0.038
1990	0.044
1991	0.050
1992	0.119
1993	0.189
1994	0.258
Source: Data from Dru Crawley, U.S. Department of Energy, Spreadsheet dated April 17, 1996.	

[h] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact.

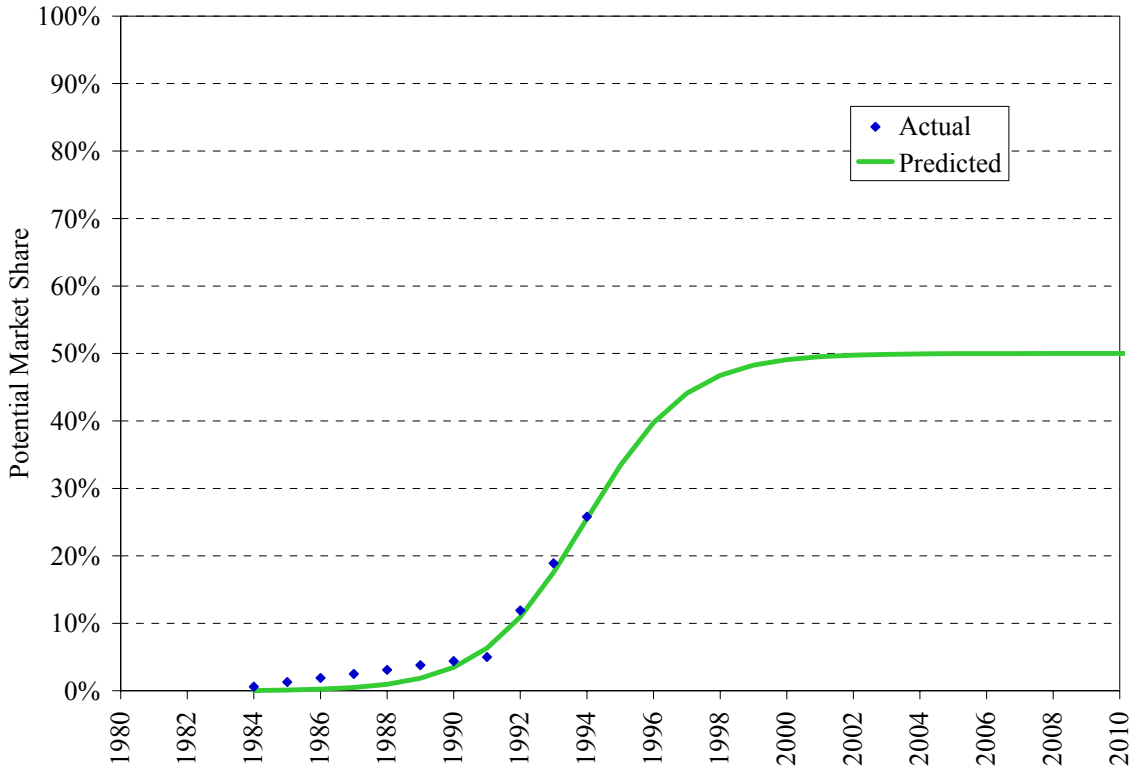

Figure 3-12. Market Penetration of DOE-2 in Use as a Design Tool [i]

[i] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact.

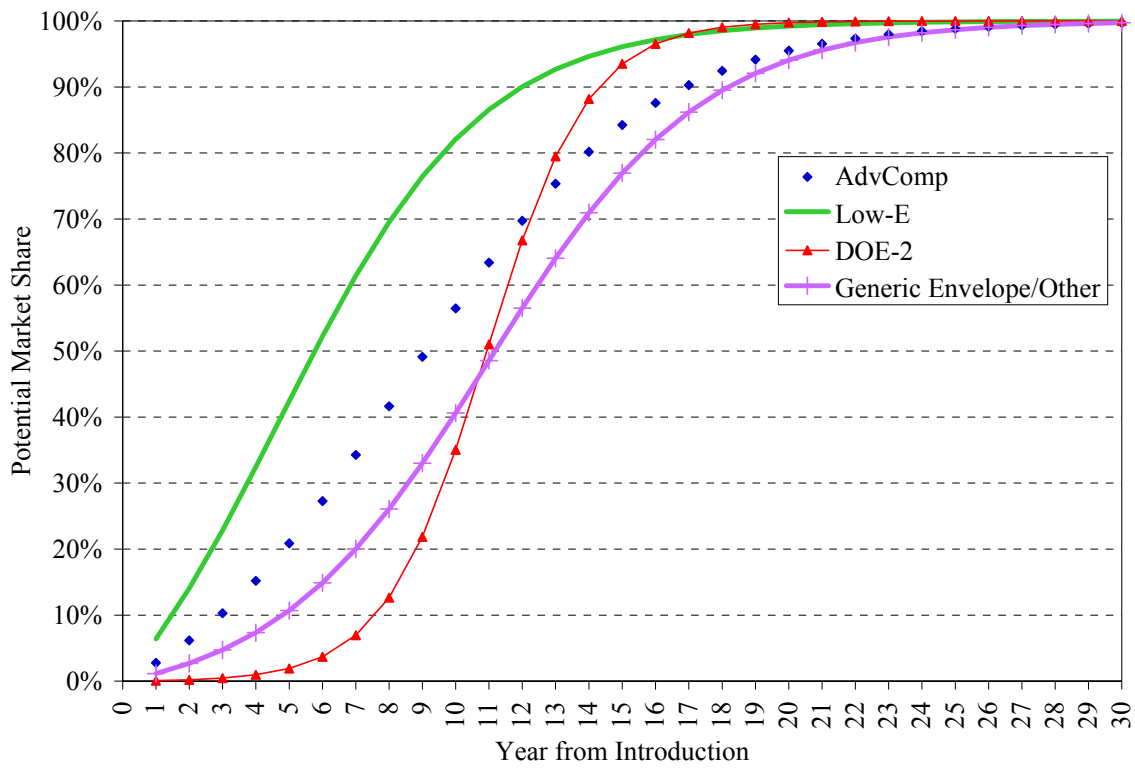

Figure 3-13. Generic Envelope/Other Diffusion Curve Compared With Other Technology Curves (Normalized to m* = 1.0) [j]

3.6 Use of the Generic Curves within the GPRA Analysis

PNNL used the generic diffusion curves to generate market penetration estimates for BT/WIP projects that do not have a forecast of annual sales targets. We created a simple penetration model spreadsheet to generate BT/WIP project-specific diffusion curves for input to the BESET model. Within the spreadsheet, the user specifies the year of market introduction for the project, the expected maximum market potential in 2020, and the technology classification that best resembles the project (lighting, HVAC, envelope, or other project).

Some of the estimated BT/WIP project diffusion curves stray from the generic classifications, depending on their individual characteristics, and use one of the specific technology parameter sets in Table 3-2.

[j] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact. The inclusion of the normalized DOE-2 curve into the development of the generic envelope/other curve does cause the generic curve to be less steep than if it were to be fit between the Advanced Compressor and Low-E window curves.

Each of the diffusion curves developed as input to the BESET model are contained within the specific project characterizations in Appendix A (BT projects) and Appendix B (WIP projects).

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Data Bucket Report for Building Envelope: Windows Program
Data Bucket Report for Commercial Building Codes Program
Data Bucket Report for Commercial Building Integration R&D Program
Data Bucket Report for Energy Star Program
Data Bucket Report for Information Outreach Program
Data Bucket Report for Lighting R&D Program
Data Bucket Report for Rebuild America Program
Data Bucket Report for Residential Building R&D Program
Data Bucket Report for Space Conditioning and Refrigeration: Refrigeration Program
Data Bucket Report for State Formula Grants Program
Data Bucket Report for Weatherization Assistance Program

5.0 List of Terms

AFUE	annual fuel utilization efficiency
AAMA	American Architectural Manufacturers Association
BESET	Building Energy Savings Estimation Tool
BT	Office of Building Technologies Programs
BTS	Office of Building Technology, State and Community Programs
CBECS	Commercial Buildings Energy Consumption Survey
CFL	compact fluorescent lights
CO	carbon monoxide
COP	coefficient of performance
DOE	U.S. Department of Energy
EER	energy efficiency ratio
EERE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPAct	Energy Policy Act of 1992
EPRI	Electric Power Research Institute
EREC	Energy Efficiency and Renewable Energy Clearinghouse
FEDS	Facility Energy Decision System
FRHOB	flame retention head oil burners
GAMA	Gas Appliance Manufacturers Association
GPRA	Government Performance and Results Act of 1993
IECC	International Energy Conservation Code
LBNL	Lawrence Berkeley National Laboratory
LTS	Lincoln Technical Services
MMBtu	million Btu
MMTCE	million metric tons carbon equivalent
MMton	million metric tons
NEMS	National Energy Modeling System
NO_x	nitrous oxides
ORNL	Oak Ridge National Laboratory
PBFA	Office of Planning, Budget Formulation, and Analysis
PM	particulate matter
PNNL	Pacific Northwest National Laboratory
QBtu	quadrillion Btu
R&D	research and development
RECS	Residential Energy Consumption Survey
SEER	seasonal energy efficiency ratio
SO_2	sulfur dioxide
TBtu	trillion Btu
VOC	volatile organic compound
WIP	Office of Weatherization and Intergovernmental Programs

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Appendix A – Building Technologies Program

This appendix describes the results of the forecasted energy savings, consumer cost savings, and carbon benefits for each of the 25 BT projects (for 2004, 2005, 2010, and 2020). Tables show forecasted benefits up to the year 2030 for all projects and decision units. The BT projects are also characterized in this appendix.

A.1 Energy Savings Analysis by Decision Unit

Decision unit benefits are reported annually. The energy savings estimates for 2010 represent energy saved in 2010 only. While these benefits are not cumulative estimates, the energy savings in 2010 are a function of all project activities from FY 2004 on, so the number of affected buildings is a cumulative value. For example, the energy saved in 2010 from CFLs is the energy saved in 2010 only, from all buildings that have had such lights installed between 2004 and 2010. Table A-1.1 summarizes the primary energy savings, the carbon equivalent reductions, and the consumer cost savings for the four BT decision units.

Table A-1.1 Summary of Benefits: Analyses of BT Projects

Decision Unit	FY 2004 Budget Request (million $)	2004	2005	2010	2020
Primary Energy Savings (TBtu/Yr)					
Residential Buildings Integration	19.2	0.6	1.6	18.3	119.4
Commercial Buildings Integration	5.0	0.0	0.5	11.8	185.6
Emerging Technologies	21.8	19.7	38.2	234.0	901.1
Equipment Standards and Analysis	9.0	0.0	3.4	91.4	383.2
Totals		20.3	43.8	355.4	1589.4
Carbon Equivalent Emission Reductions (MMTCE/Yr)					
Residential Buildings Integration	19.2	0.0	0.0	0.3	2.1
Commercial Buildings Integration	5.0	0.0	0.0	0.2	3.4
Emerging Technologies	21.8	0.3	0.7	4.4	16.2
Equipment Standards and Analysis	9.0	0.0	0.1	1.8	7.2
Totals		0.4	0.8	6.8	28.9
Consumer Cost Savings (Million $/yr)					
Residential Buildings Integration	19.2	4.0	11.0	137.0	972.0
Commercial Buildings Integration	5.0	0.0	3.0	78.0	1397.0
Emerging Technologies	21.8	135.0	258.0	1737.0	7347.0
Equipment Standards and Analysis	9.0	0.0	22.0	606.0	2938.0
Totals		139.0	294.0	2558.0	12,654.0

Total primary energy savings for all BT projects are estimated to reach 0.35 QBtu by year 2010 and 1.6 QBtu by year 2020. Figure A-1.1 charts annual energy savings for all projects for all years from FY 2004 to FY 2020. Roughly half of the savings are generated in the residential sector and half in the commercial sector.

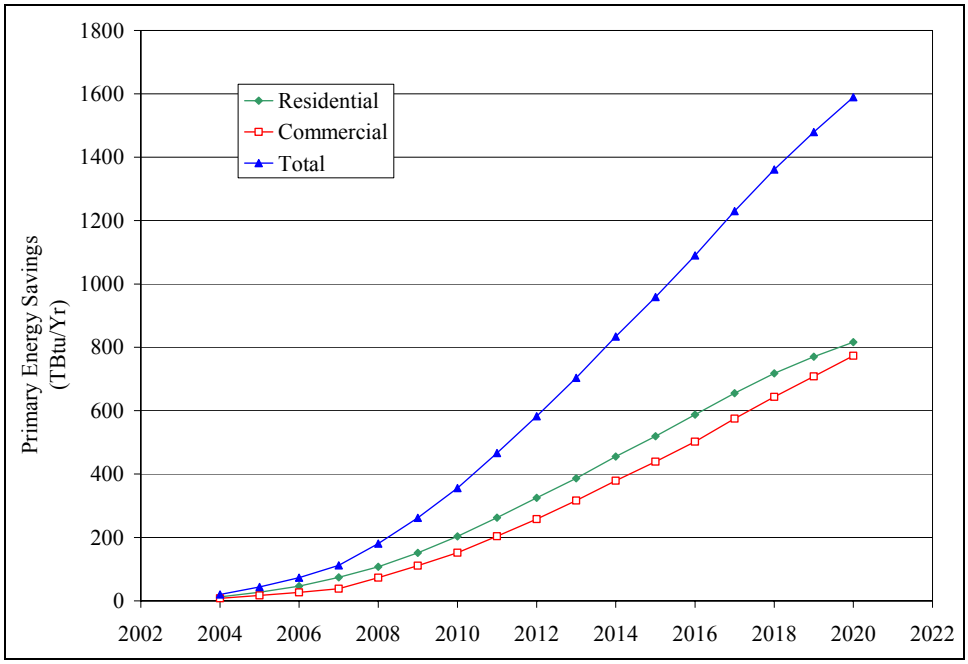

Figure A-1.1 BT Primary Energy Savings by Sector Through FY 2020

Figure A-1.2 compares the BT and WIP primary energy savings projections with the *Annual Energy Outlook 2002* building energy consumption forecasts. The FY 2004 estimates only include savings for projects that are included in the FY 2004 BT and WIP funding request. Some activities funded in previous years may contribute to total BT and WIP future energy savings but are *not* in the FY 2004 request. For example, a project that supports a rulemaking that is completed in FY 2003 would not be included in the FY 2004 request; however, this project would produce energy savings in future years.

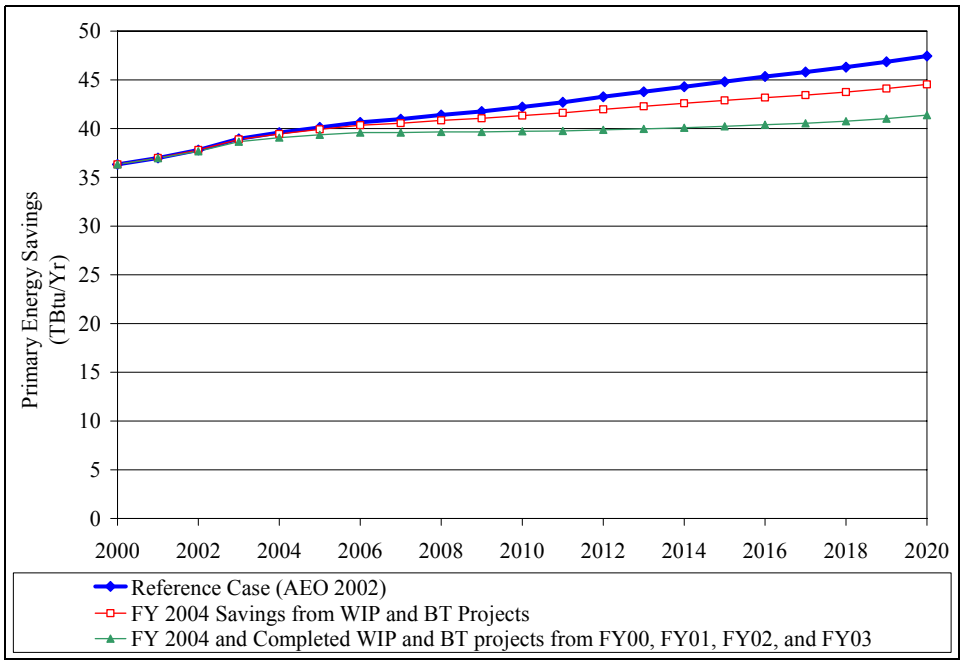

Figure A-1.2 Building Energy Consumption With and Without BT/WIP Savings

Figure A-1.2 shows savings for FY 2004 projects and projects that have been retired since FY 2000 but have future energy savings. The BT and WIP project savings projections are charted relative to the building energy consumption forecasts generated by *Annual Energy Outlook 2002*. Figure A-1.2 shows that if the forecasted savings generated by BT and WIP projects are subtracted from forecasted total building energy use, total primary building energy use remains relatively flat through 2020.

Of all BT energy savings (in year 2020), projects included in the Emerging Technologies decision unit generate over half of the total savings (see Figure A-1.3). This decision unit targets efficiency improvements for specific heating, cooling, and lighting equipment as well as shell (e.g., windows, roofs, and insulation) efficiency improvements. The Emerging Technologies decision unit makes up ~40% of the overall BT program FY 2004 budget request. The Equipment Standards decision unit makes up ~24% of the total savings while accounting for 16% of the total budget request.

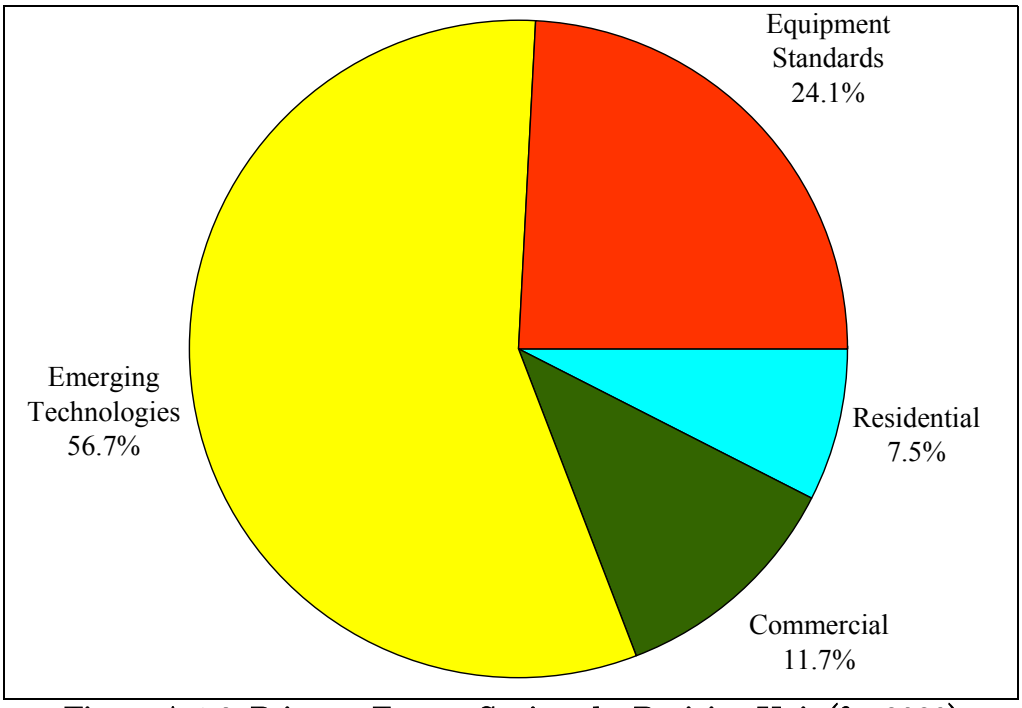

Figure A-1.3 Primary Energy Savings by Decision Unit (for 2020)

In terms of energy savings per budget dollar, the decision units within BT have fairly similar ratios (e.g., savings are proportional to budget), except for the Residential Buildings decision unit, which has a slightly lower savings-to-budget ratio than the other decision units. Projects such as Building America and Zero Energy Buildings (both contained in the Residential Buildings decision unit), which more narrowly target specific building types, tend to have relatively lower penetration rates and lower ratios of savings to budget dollar. The building codes projects (found in the Residential and Commercial Buildings decision units) have a relatively high ratio of savings to budget dollar. The buildings codes projects benefit from having high penetration rates because these standards become regulatory mandates when adopted by states. Similarly, the equipment manufacturing standards (contained in the Equipment Standards decision unit) resulting from the Energy Policy Act of 1992 (EPAct) will be a mandatory standard, which means the efficiency improvements

produced by the covered equipment will have a relatively high market penetration. Figure A-1.4 charts the FY 2004 final budget request and the energy savings of each decision unit.

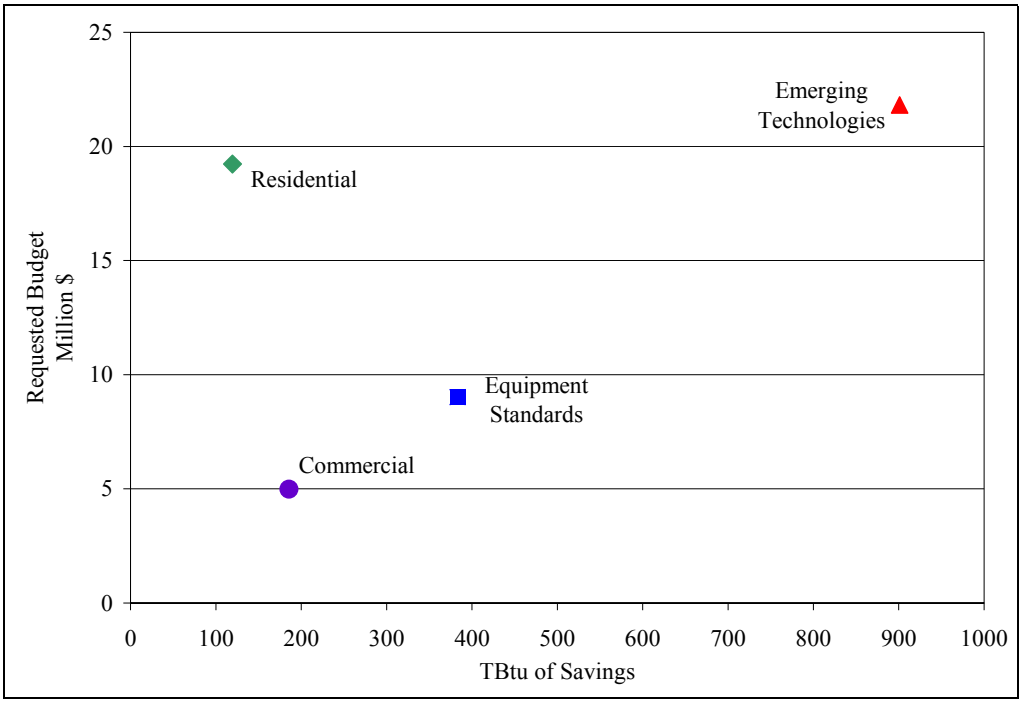

Figure A-1.4 Budget and Energy Savings Scatter Plot for BT Decision Unit

A.2 FY 2004 GPRA Metrics for BT Based on FY 2004 BT Budget Request

This section summarizes the GPRA metrics benefits estimates produced for BT and submitted to EERE's Office of Planning, Budget Formulation, and Analysis (PBFA) as part of the FY 2004 GPRA metrics effort. These estimates were produced in conjunction with the final BT FY 2004 budget request (dated February 3, 2003) and represent the expected benefits as a result of project activities funded under the FY 2004 budget request. Benefits resulting from funding in years before FY 2004 are not included, and benefits accruing from future funding are included in the estimates.

A.2.1 Scope of Analysis

The benefits estimates are developed based on a series of assumptions developed project-by-project and documented in sections A.3 through A.15. These input assumptions are critical to the analysis and are developed through an iterative process with the Project Managers. It should be noted that because BT projects are in different stages of maturity, there are varying degrees of corroborative studies available on which project information can be substantiated. Additionally, newer projects may not have estimates of future costs well-coordinated with performance estimates. For example, research projects would be expected to have more tenuous estimates of price and performance characteristics of potential products than deployment-related projects that feature products closer to market adoption. PNNL recognizes the varying levels of maturity and distance from market across projects

and that the cost and performance characteristics improve as projects mature or as they near commercialization.

A.2.2 Comparison of FY 2003 GPRA Metrics with FY 2004 GPRA Metrics[a]

Energy savings estimates are reported to PBFA at a decision unit level; however, this section explains changes that arise at the individual project/technology level. While estimates at this level are not reported to PBFA as part of the GPRA metrics, they provide a useful planning tool for BT and variations should be understood.

Overall, the estimated energy savings from BT projects through 2020 are lower than those associated with the FY 2003 request. The FY 2003 estimate of 0.42 QBtu in 2010 falls to 0.37 quadrillion Btu (QBtu) for the FY 2004 request, and the FY 2003 estimate of 1.67 QBtu in 2020 falls to 1.59 QBtu for the FY 2004 request.

The discussion has been divided into five categories relative to primary energy savings in the year 2020:

1. Projects characterized in FY 2003 but not in FY 2004
2. Projects that have not changed significantly between FY 2003 and FY 2004
3. Projects that have changed 25% to 50% between FY 2003 and FY 2004
4. Projects that have changed more than 50% between FY 2003 and FY 2004
5. Projects characterized in FY 2004 but not in FY 2003.

Projects that fall into the first category have been completed or terminated and are not in the FY 2004 request. Projects that fall into the fifth category were not characterized in the FY 2003 metrics either because they were new to the FY 2004 request or because not enough information was available about them in FY 2003 to characterize them.

In general, projects are included in GPRA based on whether they are a line item in the initial budget request with a specific funding allocation. Occasionally, projects do not appear as a line item in the initial funding request but do appear in the final request. These projects are characterized within GPRA metrics only if enough information is available to characterize the project in a short period of time. For projects covering a suite of technologies, the technologies characterized are based on discussions with the project manager. This suite of technologies may change from year to year as the project manager changes focus. The suite of technologies is meant to represent the project, not to capture all funded activities. Any other projects not mentioned did not result in any change in out-year primary energy savings estimates. The impact of these categories of projects is shown in Table A-2.1.

[a] FY 2003 GPRA metrics were based on BESET Run 4N; FY 2004 GPRA metrics were based on BESET Run 5.

Table A-2.1 Impact of Projects

Changes by Category	Year 2020 (TBtu)
FY 2003 Estimate	1,672
Less	
1. Projects characterized in FY 2003 but not in FY 2004	-132
Plus	
2. Projects that have not changed significantly between FY 2003 and FY 2004	25
3. Projects that have changed 25% to 50% between FY 2003 and FY 2004	-26
4. Projects that have changed more than 50% between FY 2003 and FY 2004	29
5. Projects characterized in FY 2004 but not in FY 2003	72
Equals	
FY 2004 Estimate	**1,589**

- Projects characterized in FY 2003 but not in FY 2004 – One project fits this category: Lighting R&D – Two-Photon Phosphors. In FY 2004, the two-photon phosphors activity was not funded in anticipation of the Next Generation Lighting Initiative.

- Projects that have not changed significantly between FY 2003 and FY 2004 – The modeling methods or characterizations for eight projects or technologies did not change significantly between FY 2003 and FY 2004:

  – Residential Technology R&D
  – Commercial Technology R&D
  – Next Generation Lighting (formerly Solid State Lighting)
  – Space Conditioning and Refrigeration R&D: Residential HVAC Distribution System
  – Space Conditioning and Refrigeration R&D: Advanced Electric Heat Pump Water Heater
  – Space Conditioning and Refrigeration R&D: Refrigerant Meter
  – Analysis Tools and Design Strategies
  – Equipment Standards and Analysis: EPAct Standards.

- Projects that have changed 25% to 50% between FY 2003 and FY 2004 – One project fits this category: Residential Building Codes. The energy savings from this project decreased almost 26 TBtu in 2020 because the planned code development efforts were re-evaluated.

- Projects that have changed more than 50% between FY 2003 and FY 2004 – Four projects fit this category:

  – Commercial Building Codes: The energy savings from this project decreased ~55 TBtu in 2020 because the planned code development efforts were re-evaluated.

  – Space Conditioning and Refrigeration R&D: Commercial Refrigeration. The energy savings from this project increased ~12 TBtu in 2020 because of increases in the baseline building stock forecast.

- Appliances & Emerging Technologies R&D: Recessed Can Lights. The energy savings from this project increased by almost 30 TBtu because of an algorithm correction that more correctly models "new" buildings. This technology was assumed to be applicable only to new construction.

- Standards: Distribution Transformers. The energy savings from this project increased by ~42 TBtu because of increases in the base transformer sales forecast.

- Projects characterized in FY 2004 but not in FY 2003 – a new initiative was added to the BT budget request for FY 2004 – Zero Energy Buildings. The Zero Energy Buildings project is expected to result in almost 72 TBtu of savings annually by 2020.

A.2.3 FY 2004 GPRA Metrics – Detailed Tables

Tables A-2.2 through A-2.19 are included here to show forecasted benefits up to the year 2030 for all projects and decision units. The benefit estimates available include:

- Energy Savings Benefits Tables (TBtu per year)
  - Total Primary Energy Savings
  - Total Site Energy Savings
  - Primary Electricity savings
  - Primary Non-Electric Savings
  - Site Electricity Savings
  - Site Natural Gas Savings
  - Site Oil Savings.

- Environmental Benefits Tables (million metric tons per year)
  - Carbon Equivalent Emissions Reductions
  - SO_2 Emissions Reductions
  - NO_X Emissions Reductions
  - CO Emissions Reductions
  - Particulate matter (PM) Emissions Reductions
  - Volatile Organic VOC Emissions Reductions.

- Financial Benefits Tables (million $ per year)
  - Consumer Cost Savings
  - Non-Energy Cost Savings
  - Incremental Investment.

- Employment and Income Impacts (from ImBuild)
  - Employment (thousand jobs per year)
  - Income (million $ per year).

In all benefits tables, project benefits are reported annually. The energy savings estimate for 2010 represents energy saved in 2010 only. These are not cumulative benefits estimates. However, the energy saved in 2010 is a function of all project activities from FY 2004 on, so that the number of affected buildings is a cumulative value. For example, the energy saved in 2010 from recessed can lights (within Appliances and Emerging

Technologies R&D project) is the energy saved in 2010 only, from all buildings that have had such lights installed any time between 2004 and 2010.

Reductions in emissions from BT projects are calculated from GPRA metrics estimates of energy savings by fuel type, multiplied by emissions coefficients provided by PBFA for use in GPRA metrics.

The consumer cost savings, as defined in EERE GPRA guidance, represent the monetary value of the energy saving estimates. These estimates are calculated from GPRA metrics estimates of energy savings by sector and fuel type, multiplied by energy price forecasts provided by PBFA for use in GPRA metrics.

BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.2. Primary Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.6**	**1.6**	**3.5**	**5.7**	**8.9**	**18.3**	**58.5**	**119.4**	**200.8**	**302.6**
Research & Development (Building America)	0.3	0.9	2.0	3.3	5.0	9.1	17.2	21.0	23.2	25.4
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.1	0.8	9.9	26.8	45.3	64.8
Zero Energy Buildings	0.3	0.8	1.5	2.5	3.8	8.3	31.4	71.6	132.3	212.5
2 Commercial Buildings Integration	**0.0**	**0.5**	**1.0**	**1.5**	**2.8**	**11.8**	**102.7**	**185.6**	**266.1**	**345.7**
Research & Development	0.0	0.5	1.0	1.5	2.8	10.9	88.4	140.6	178.6	215.2
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.9	14.4	45.0	87.5	130.5
3 Emerging Technologies	**19.7**	**38.2**	**61.9**	**94.8**	**132.5**	**234.0**	**558.0**	**901.1**	**1,124.3**	**1,269.2**
Lighting R&D: Controls	1.3	2.5	4.0	6.1	8.6	14.7	30.8	39.7	50.3	59.9
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.6	97.9	161.5
Refrigeration R&D: Res. HVAC Dist. System	1.6	3.9	7.1	11.6	17.7	36.1	104.5	113.5	61.6	38.8
Refrigeration R&D: Adv. Elec HPWH	0.0	0.1	0.3	0.7	1.4	3.6	21.5	54.4	68.8	43.8
Refrigeration R&D: Commercial Refrigeration	0.4	0.9	1.7	2.9	4.4	9.2	29.6	34.6	16.2	3.1
Refrigeration R&D: Refrigerant Meter	0.0	0.3	0.9	2.0	3.7	9.8	53.4	132.9	162.8	95.8
Appliances & Emerging Tech R&D: HPWH	2.1	3.4	5.3	8.3	12.2	24.6	55.5	65.2	79.0	94.5
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.7	1.2	1.6	1.9	2.3	3.0	3.4	4.0	4.6
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.2	0.6	1.2	2.2	7.0	21.0	25.3	30.1	35.2
Appliances & Emerging Tech R&D: Recessed Can Lights	0.1	0.3	0.8	2.0	3.8	9.7	27.9	33.8	33.8	33.9
Appliances & Emerging Tech R&D: R-Lamp	2.5	6.6	12.1	19.4	25.2	33.5	3.1	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	6.0	8.6	11.3	14.6	17.4	23.8	38.2	56.2	78.2	102.5
Window Technologies: Superwindows	5.5	9.6	14.3	20.4	27.8	46.9	122.1	194.2	274.3	361.7
Thermal Insulation: Quick Fill Walls	0.0	0.1	0.1	0.2	0.3	0.5	2.3	5.1	8.3	11.8
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.3	4.4	14.3	24.5	35.1
Thermal Insulation: Moisture/Wet Insulation	0.2	0.8	1.6	2.8	4.3	8.2	22.2	42.7	65.7	91.0
Analysis Tools and Design	0.1	0.3	0.6	1.1	1.6	3.7	18.6	41.4	68.9	96.1
4 Equipment Standards and Analysis	**0.0**	**3.4**	**6.8**	**10.4**	**36.2**	**91.4**	**239.3**	**383.2**	**445.8**	**511.2**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	4.7	17.4	30.9	45.7	62.1
Standards: EPAct Standards	0.0	3.4	6.8	10.4	26.8	60.2	153.8	241.5	278.1	315.0
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	9.4	26.5	68.1	110.9	122.0	134.1
Building Technologies Total	**20.3**	**43.8**	**73.1**	**112.4**	**180.4**	**355.4**	**958.6**	**1,589.4**	**2,037.0**	**2,428.7**

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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.3. Site Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.4**	**1.0**	**2.2**	**3.7**	**5.8**	**12.4**	**41.8**	**86.9**	**144.9**	**216.5**
Research & Development (Building America)	0.2	0.6	1.4	2.3	3.5	6.6	12.8	15.8	17.4	19.1
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.1	0.7	8.6	23.4	39.2	55.8
Zero Energy Buildings	0.2	0.4	0.8	1.4	2.3	5.1	20.4	47.7	88.2	141.6
2 Commercial Buildings Integration	**0.0**	**0.3**	**0.6**	**0.8**	**1.7**	**7.0**	**62.5**	**109.2**	**148.3**	**186.7**
Research & Development	0.0	0.3	0.6	0.8	1.7	6.7	56.7	90.5	111.9	132.5
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.3	5.8	18.8	36.4	54.2
3 Emerging Technologies	**9.0**	**18.1**	**30.5**	**47.1**	**68.4**	**130.6**	**346.5**	**555.7**	**686.4**	**796.9**
Lighting R&D: Controls	0.4	0.8	1.3	2.1	3.0	5.6	12.7	17.2	21.8	25.9
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.3	42.4	69.9
Refrigeration R&D: Res. HVAC Dist. System	1.1	2.7	5.0	8.2	12.7	26.8	80.0	88.1	47.0	28.5
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.1	0.2	0.5	1.4	8.9	23.5	29.8	19.0
Refrigeration R&D: Commercial Refrigeration	0.1	0.3	0.6	1.1	1.7	3.9	13.5	16.5	7.7	1.5
Refrigeration R&D: Refrigerant Meter	0.0	0.1	0.3	0.7	1.3	3.7	22.1	57.5	70.5	41.5
Appliances & Emerging Tech R&D: HPWH	0.7	1.1	1.8	2.8	4.3	9.3	22.9	28.2	34.2	40.9
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.2	0.4	0.5	0.7	0.9	1.2	1.5	1.7	2.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.2	0.6	1.2	2.2	7.0	21.0	25.3	30.1	35.2
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.1	0.3	0.7	1.3	3.7	11.4	14.5	14.6	14.6
Appliances & Emerging Tech R&D: R-Lamp	0.8	2.1	4.1	6.5	8.8	12.7	1.3	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	1.2	1.9	2.7	3.6	4.6	7.3	13.8	22.4	32.0	42.5
Window Technologies: Superwindows	4.4	7.6	11.4	16.2	22.3	38.1	100.5	160.3	224.4	293.3
Thermal Insulation: Quick Fill Walls	0.0	0.1	0.1	0.1	0.2	0.5	2.0	4.6	7.4	10.5
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.3	4.1	13.4	23.0	32.9
Thermal Insulation: Moisture/Wet Insulation	0.2	0.8	1.6	2.7	4.1	7.9	20.8	39.5	60.3	83.2
Analysis Tools and Design	0.1	0.1	0.3	0.4	0.7	1.8	10.2	23.7	39.7	55.5
4 Equipment Standards and Analysis	**0.0**	**1.1**	**2.3**	**3.5**	**13.3**	**39.4**	**113.8**	**190.8**	**228.9**	**269.0**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	4.7	17.4	30.9	45.9	62.3
Standards: EPAct Standards	0.0	1.1	2.3	3.5	10.0	24.6	68.2	111.9	130.2	148.6
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	3.3	10.1	28.1	48.0	52.8	58.1
Building Technologies Total	**9.3**	**20.5**	**35.5**	**55.1**	**89.2**	**189.5**	**564.6**	**942.6**	**1,208.5**	**1,469.0**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.4. Primary Electricity Energy Savings (TBtu/Year)

		2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1	**Residential Buildings Integration**	**0.3**	**0.9**	**1.9**	**3.1**	**4.8**	**9.4**	**28.5**	**57.3**	**98.6**	**151.8**
	Research & Development (Building America)	0.2	0.4	0.9	1.5	2.3	4.0	7.5	9.2	10.1	11.1
	Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.2	2.2	6.0	10.6	15.8
	Zero Energy Buildings	0.2	0.5	1.0	1.6	2.5	5.1	18.8	42.1	77.8	124.9
2	**Commercial Buildings Integration**	**0.0**	**0.3**	**0.6**	**1.0**	**1.8**	**7.6**	**68.5**	**134.7**	**207.8**	**280.4**
	Research & Development	0.0	0.3	0.6	1.0	1.8	6.8	53.9	88.4	117.6	145.8
	Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.9	14.6	46.2	90.3	134.5
3	**Emerging Technologies**	**15.8**	**29.7**	**47.4**	**72.0**	**98.7**	**166.3**	**360.5**	**609.2**	**772.0**	**832.9**
	Lighting R&D: Controls	1.3	2.5	4.0	6.1	8.6	14.7	30.8	39.7	50.3	59.9
	Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.6	97.9	161.5
	Refrigeration R&D: Res. HVAC Dist. System	0.7	1.8	3.2	5.2	7.7	15.1	41.7	44.8	25.9	18.2
	Refrigeration R&D: Adv. Elec HPWH	0.0	0.1	0.3	0.7	1.4	3.6	21.5	54.4	68.8	43.8
	Refrigeration R&D: Commercial Refrigeration	0.4	0.9	1.6	2.7	4.1	8.5	27.5	31.9	14.9	2.9
	Refrigeration R&D: Refrigerant Meter	0.0	0.3	0.9	2.0	3.7	9.8	53.4	132.9	162.8	95.8
	Appliances & Emerging Tech R&D: HPWH	2.1	3.4	5.3	8.3	12.2	24.6	55.5	65.2	79.0	94.5
	Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.7	1.2	1.6	1.9	2.3	3.0	3.4	4.0	4.6
	Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Appliances & Emerging Tech R&D: Recessed Can Lights	0.1	0.3	0.8	2.0	3.8	9.7	28.0	33.9	33.9	33.9
	Appliances & Emerging Tech R&D: R-Lamp	2.5	6.6	12.1	19.4	25.2	33.5	3.1	0.0	0.0	0.0
	Window Technologies: Electrochromic Windows	7.0	10.0	13.0	16.6	19.7	26.6	41.5	59.6	81.6	105.8
	Window Technologies: Superwindows	1.7	2.9	4.4	6.4	8.6	14.2	36.8	59.7	88.1	120.5
	Thermal Insulation: Quick Fill Walls	0.0	0.0	0.0	0.0	0.1	0.1	0.4	0.9	1.5	2.2
	Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.1	0.7	1.6	2.7	3.9
	Thermal Insulation: Moisture/Wet Insulation	0.0	0.1	0.1	0.1	0.2	0.5	2.3	5.5	9.4	13.8
	Analysis Tools and Design	0.1	0.3	0.6	0.9	1.4	3.1	14.3	31.1	51.4	71.5
4	**Equipment Standards and Analysis**	**0.0**	**3.4**	**6.8**	**10.4**	**35.3**	**83.8**	**213.9**	**339.2**	**382.6**	**427.2**
	Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.3
	Standards: EPAct Standards	0.0	3.4	6.8	10.4	25.9	57.3	145.9	228.5	260.8	293.4
	Standards: Distribution Transformers	0.0	0.0	0.0	0.0	9.4	26.5	68.1	110.9	122.0	134.1
	Building Technologies Total	**16.2**	**34.3**	**56.7**	**86.5**	**140.6**	**267.1**	**671.4**	**1,140.4**	**1,461.0**	**1,692.3**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.5. Primary Non-Electric Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.3**	**0.7**	**1.6**	**2.6**	**4.1**	**8.9**	**30.0**	**62.1**	**102.2**	**150.8**
Research & Development (Building America)	0.2	0.5	1.1	1.7	2.7	5.1	9.7	11.8	13.1	14.3
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.1	0.7	7.7	20.8	34.6	48.9
Zero Energy Buildings	0.1	0.3	0.5	0.9	1.4	3.2	12.6	29.5	54.5	87.5
2 **Commercial Buildings Integration**	**0.0**	**0.2**	**0.3**	**0.5**	**1.0**	**4.1**	**34.2**	**50.9**	**58.3**	**65.3**
Research & Development	0.0	0.2	0.3	0.5	1.0	4.1	34.5	52.2	61.0	69.4
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-1.3	-2.7	-4.0
3 Emerging Technologies	**3.9**	**8.5**	**14.5**	**22.7**	**33.8**	**67.6**	**197.5**	**292.0**	**352.2**	**436.3**
Lighting R&D: Controls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Res. HVAC Dist. System	0.9	2.1	3.9	6.4	10.0	21.1	62.8	68.7	35.8	20.6
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Commercial Refrigeration	0.0	0.1	0.1	0.2	0.3	0.6	2.2	2.6	1.2	0.2
Refrigeration R&D: Refrigerant Meter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.2	0.6	1.2	2.2	7.0	21.0	25.3	30.1	35.2
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1
Appliances & Emerging Tech R&D: R-Lamp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	-1.0	-1.4	-1.7	-2.0	-2.3	-2.8	-3.4	-3.4	-3.4	-3.3
Window Technologies: Superwindows	3.8	6.6	9.9	14.1	19.2	32.7	85.3	134.4	186.3	241.1
Thermal Insulation: Quick Fill Walls	0.0	0.1	0.1	0.1	0.2	0.4	1.8	4.2	6.7	9.5
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.3	3.8	12.8	21.9	31.2
Thermal Insulation: Moisture/Wet Insulation	0.2	0.8	1.6	2.7	4.1	7.7	19.8	37.1	56.3	77.2
Analysis Tools and Design	0.0	0.0	0.1	0.1	0.2	0.6	4.3	10.3	17.5	24.5
4 Equipment Standards and Analysis	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**7.6**	**25.4**	**44.0**	**63.2**	**84.0**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	4.7	17.5	31.0	45.9	62.4
Standards: EPAct Standards	0.0	0.0	0.0	0.0	0.9	2.9	7.9	13.0	17.3	21.6
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Building Technologies Total	**4.2**	**9.4**	**16.5**	**25.9**	**39.9**	**88.3**	**287.1**	**448.9**	**576.0**	**736.5**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.6. Site Electricity Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.1**	**0.3**	**0.6**	**1.1**	**1.7**	**3.5**	**11.8**	**24.8**	**42.7**	**65.7**
Research & Development (Building America)	0.0	0.1	0.3	0.5	0.8	1.5	3.1	4.0	4.4	4.8
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.1	0.9	2.6	4.6	6.9
Zero Energy Buildings	0.1	0.2	0.3	0.5	0.9	2.0	7.8	18.2	33.7	54.1
2 Commercial Buildings Integration	**0.0**	**0.1**	**0.2**	**0.3**	**0.6**	**2.9**	**28.3**	**58.3**	**90.0**	**121.4**
Research & Development	0.0	0.1	0.2	0.3	0.6	2.6	22.3	38.3	50.9	63.1
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.3	6.0	20.0	39.1	58.2
3 Emerging Technologies	**5.0**	**9.6**	**15.9**	**24.3**	**34.6**	**63.0**	**149.0**	**263.7**	**334.2**	**360.5**
Lighting R&D: Controls	0.4	0.8	1.3	2.1	3.0	5.6	12.7	17.2	21.8	25.9
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.3	42.4	69.9
Refrigeration R&D: Res. HVAC Dist. System	0.2	0.6	1.1	1.7	2.7	5.7	17.2	19.4	11.2	7.9
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.1	0.2	0.5	1.4	8.9	23.5	29.8	19.0
Refrigeration R&D: Commercial Refrigeration	0.1	0.3	0.5	0.9	1.4	3.2	11.3	13.8	6.5	1.3
Refrigeration R&D: Refrigerant Meter	0.0	0.1	0.3	0.7	1.3	3.7	22.1	57.5	70.5	41.5
Appliances & Emerging Tech R&D: HPWH	0.7	1.1	1.8	2.8	4.3	9.3	22.9	28.2	34.2	40.9
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.2	0.4	0.5	0.7	0.9	1.2	1.5	1.7	2.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.1	0.3	0.7	1.3	3.7	11.6	14.7	14.7	14.7
Appliances & Emerging Tech R&D: R-Lamp	0.8	2.1	4.1	6.6	8.9	12.7	1.3	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	2.2	3.2	4.4	5.6	6.9	10.1	17.2	25.8	35.3	45.8
Window Technologies: Superwindows	0.5	1.0	1.5	2.2	3.0	5.4	15.2	25.9	38.1	52.2
Thermal Insulation: Quick Fill Walls	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.7	1.0
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.7	1.2	1.7
Thermal Insulation: Moisture/Wet Insulation	0.0	0.0	0.0	0.0	0.1	0.2	1.0	2.4	4.1	6.0
Analysis Tools and Design	0.0	0.1	0.2	0.3	0.5	1.2	5.9	13.4	22.3	31.0
4 Equipment Standards and Analysis	**0.0**	**1.1**	**2.3**	**3.5**	**12.4**	**31.7**	**88.4**	**146.9**	**165.6**	**184.9**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
Standards: EPAct Standards	0.0	1.1	2.3	3.5	9.1	21.7	60.3	98.9	112.9	127.0
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	3.3	10.1	28.1	48.0	52.8	58.1
Building Technologies Total	**5.2**	**11.1**	**19.1**	**29.2**	**49.3**	**101.2**	**277.4**	**493.7**	**632.5**	**732.6**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.7. Site Natural Gas Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.2**	**0.6**	**1.4**	**2.3**	**3.7**	**7.8**	**25.2**	**51.1**	**83.2**	**122.0**
Research & Development (Building America)	0.1	0.4	1.0	1.6	2.6	4.8	9.2	11.2	12.4	13.6
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.1	0.5	6.2	17.0	28.5	40.6
Zero Energy Buildings	0.1	0.2	0.4	0.7	1.1	2.4	9.8	22.9	42.3	67.9
2 Commercial Buildings Integration	**0.0**	**0.2**	**0.3**	**0.5**	**0.9**	**3.7**	**30.5**	**45.6**	**52.6**	**59.2**
Research & Development	0.0	0.2	0.3	0.5	0.9	3.7	30.7	46.9	55.3	63.2
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-1.3	-2.7	-4.0
3 Emerging Technologies	**2.8**	**6.6**	**11.7**	**18.7**	**28.4**	**58.6**	**174.9**	**259.7**	**312.3**	**388.6**
Lighting R&D: Controls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Res. HVAC Dist. System	0.8	2.0	3.8	6.2	9.6	20.3	60.4	66.1	34.3	19.7
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Commercial Refrigeration	0.0	0.1	0.1	0.2	0.3	0.6	2.2	2.6	1.2	0.2
Refrigeration R&D: Refrigerant Meter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.2	0.6	1.2	2.2	7.0	21.0	25.3	30.1	35.2
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1
Appliances & Emerging Tech R&D: R-Lamp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	-1.0	-1.3	-1.6	-2.0	-2.3	-2.7	-3.2	-3.1	-3.0	-2.8
Window Technologies: Superwindows	2.8	4.8	7.2	10.3	14.2	24.5	66.2	107.9	152.8	201.2
Thermal Insulation: Quick Fill Walls	0.0	0.1	0.1	0.1	0.2	0.4	1.7	3.9	6.4	9.1
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.2	3.4	11.6	20.1	28.8
Thermal Insulation: Moisture/Wet Insulation	0.2	0.8	1.5	2.6	4.0	7.6	19.4	36.1	54.6	74.9
Analysis Tools and Design	0.0	0.0	0.1	0.1	0.2	0.6	3.9	9.4	15.9	22.4
4 Equipment Standards and Analysis	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**7.6**	**25.4**	**44.0**	**63.2**	**84.0**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	4.7	17.5	31.0	45.9	62.4
Standards: EPAct Standards	0.0	0.0	0.0	0.0	0.9	2.9	7.9	13.0	17.3	21.6
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Building Technologies Total	**3.1**	**7.4**	**13.4**	**21.5**	**33.9**	**77.7**	**255.9**	**400.4**	**511.3**	**653.8**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.8. Site Fuel Oil Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.0**	**0.1**	**0.2**	**0.3**	**0.4**	**1.1**	**4.8**	**11.0**	**19.0**	**28.8**
Research & Development (Building America)	0.0	0.0	0.1	0.1	0.1	0.2	0.5	0.6	0.7	0.7
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.1	1.5	3.8	6.1	8.4
Zero Energy Buildings	0.0	0.1	0.1	0.2	0.3	0.7	2.8	6.6	12.3	19.7
2 Commercial Buildings Integration	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.5**	**3.7**	**5.3**	**5.8**	**6.1**
Research & Development	0.0	0.0	0.0	0.1	0.1	0.5	3.7	5.3	5.8	6.1
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 Emerging Technologies	**1.1**	**1.9**	**2.8**	**4.0**	**5.4**	**9.1**	**22.6**	**32.2**	**39.9**	**47.7**
Lighting R&D: Controls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Res. HVAC Dist. System	0.0	0.1	0.1	0.2	0.4	0.8	2.4	2.6	1.4	0.9
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Commercial Refrigeration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Refrigerant Meter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: R-Lamp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5
Window Technologies: Superwindows	1.1	1.8	2.7	3.8	5.0	8.2	19.2	26.6	33.5	39.9
Thermal Insulation: Quick Fill Walls	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.1	1.8	2.5
Thermal Insulation: Moisture/Wet Insulation	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.1	1.7	2.4
Analysis Tools and Design	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.9	1.5	2.1
4 Equipment Standards and Analysis	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standards: EPAct Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Building Technologies Total	**1.1**	**2.0**	**3.1**	**4.3**	**6.0**	**10.6**	**31.2**	**48.6**	**64.6**	**82.6**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.9. Carbon Equivalent Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.010**	**0.028**	**0.060**	**0.103**	**0.159**	**0.326**	**1.026**	**2.068**	**3.491**	**5.279**
Research & Development (Building America)	0.005	0.015	0.034	0.057	0.086	0.157	0.291	0.352	0.389	0.425
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.001	0.014	0.164	0.437	0.738	1.057
Zero Energy Buildings	0.005	0.013	0.027	0.046	0.072	0.155	0.571	1.280	2.364	3.796
2 Commercial Buildings Integration	**0.000**	**0.009**	**0.017**	**0.027**	**0.052**	**0.218**	**1.876**	**3.383**	**4.914**	**6.429**
Research & Development	0.000	0.009	0.017	0.027	0.052	0.201	1.588	2.501	3.197	3.869
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.018	0.287	0.882	1.717	2.560
3 Emerging Technologies	**0.348**	**0.690**	**1.142**	**1.808**	**2.524**	**4.432**	**10.137**	**16.229**	**20.307**	**22.744**
Lighting R&D: Controls	0.024	0.047	0.077	0.124	0.175	0.301	0.612	0.773	0.979	1.166
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.867	1.904	3.142
Refrigeration R&D: Res. HVAC Dist. System	0.025	0.064	0.118	0.199	0.303	0.616	1.746	1.875	1.026	0.656
Refrigeration R&D: Adv. Elec HPWH	0.000	0.002	0.006	0.015	0.028	0.073	0.429	1.058	1.338	0.852
Refrigeration R&D: Commercial Refrigeration	0.007	0.017	0.032	0.057	0.088	0.184	0.578	0.659	0.308	0.060
Refrigeration R&D: Refrigerant Meter	0.000	0.005	0.017	0.041	0.076	0.201	1.062	2.586	3.168	1.863
Appliances & Emerging Tech R&D: HPWH	0.038	0.063	0.102	0.168	0.248	0.503	1.104	1.268	1.536	1.838
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.012	0.022	0.032	0.039	0.048	0.060	0.066	0.077	0.089
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.003	0.008	0.017	0.031	0.101	0.302	0.365	0.433	0.507
Appliances & Emerging Tech R&D: Recessed Can Lights	0.001	0.005	0.016	0.040	0.077	0.199	0.555	0.658	0.659	0.659
Appliances & Emerging Tech R&D: R-Lamp	0.045	0.124	0.234	0.393	0.513	0.686	0.063	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.111	0.167	0.228	0.307	0.367	0.504	0.777	1.110	1.537	2.009
Window Technologies: Superwindows	0.091	0.160	0.242	0.352	0.479	0.806	2.063	3.240	4.575	6.031
Thermal Insulation: Quick Fill Walls	0.000	0.001	0.002	0.003	0.004	0.009	0.035	0.079	0.129	0.183
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.005	0.069	0.220	0.377	0.539
Thermal Insulation: Moisture/Wet Insulation	0.003	0.012	0.024	0.041	0.063	0.122	0.335	0.648	1.002	1.393
Analysis Tools and Design	0.002	0.006	0.012	0.021	0.031	0.073	0.349	0.757	1.260	1.757
4 Equipment Standards and Analysis	**0.000**	**0.064**	**0.132**	**0.210**	**0.732**	**1.828**	**4.622**	**7.234**	**8.354**	**9.522**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.068	0.250	0.444	0.658	0.893
Standards: EPAct Standards	0.000	0.064	0.132	0.210	0.541	1.216	3.017	4.632	5.324	6.019
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.191	0.544	1.354	2.158	2.373	2.610
Building Technologies Total	**0.358**	**0.791**	**1.351**	**2.147**	**3.467**	**6.804**	**17.660**	**28.914**	**37.067**	**43.974**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.10. SO_2 Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.004**	**0.011**	**0.021**	**0.036**	**0.055**
Research & Development (Building America)	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.003	0.003	0.003
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.006	0.009
Zero Energy Buildings	0.000	0.000	0.000	0.001	0.001	0.002	0.007	0.015	0.027	0.043
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.003**	**0.021**	**0.038**	**0.058**	**0.077**
Research & Development	0.000	0.000	0.000	0.000	0.001	0.002	0.017	0.026	0.034	0.042
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.012	0.024	0.035
3 Emerging Technologies	**0.004**	**0.008**	**0.014**	**0.024**	**0.033**	**0.057**	**0.114**	**0.177**	**0.224**	**0.244**
Lighting R&D: Controls	0.000	0.001	0.001	0.002	0.003	0.005	0.009	0.010	0.013	0.016
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.026	0.042
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.000	0.001	0.002	0.003	0.005	0.013	0.013	0.008	0.005
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.001	0.006	0.014	0.018	0.011
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.001	0.001	0.003	0.008	0.008	0.004	0.001
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.001	0.001	0.003	0.015	0.035	0.043	0.025
Appliances & Emerging Tech R&D: HPWH	0.000	0.001	0.001	0.003	0.004	0.008	0.016	0.017	0.021	0.025
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.001	0.001	0.003	0.008	0.009	0.009	0.009
Appliances & Emerging Tech R&D: R-Lamp	0.001	0.002	0.003	0.006	0.008	0.011	0.001	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.001	0.002	0.003	0.005	0.006	0.008	0.012	0.015	0.021	0.028
Window Technologies: Superwindows	0.001	0.002	0.003	0.004	0.005	0.009	0.021	0.030	0.041	0.053
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.005
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.009	0.014	0.020
4 Equipment Standards and Analysis	**0.000**	**0.001**	**0.002**	**0.003**	**0.011**	**0.026**	**0.061**	**0.089**	**0.100**	**0.112**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Standards: EPAct Standards	0.000	0.001	0.002	0.003	0.008	0.018	0.041	0.060	0.068	0.077
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.003	0.008	0.019	0.029	0.032	0.035
Building Technologies Total	**0.004**	**0.009**	**0.017**	**0.029**	**0.047**	**0.090**	**0.206**	**0.325**	**0.417**	**0.487**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.11. NO_X Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.003**	**0.008**	**0.017**	**0.028**	**0.043**
Research & Development (Building America)	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.003
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.006	0.008
Zero Energy Buildings	0.000	0.000	0.000	0.000	0.001	0.001	0.005	0.011	0.020	0.031
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**	**0.016**	**0.029**	**0.042**	**0.055**
Research & Development	0.000	0.000	0.000	0.000	0.000	0.002	0.013	0.021	0.027	0.033
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.008	0.015	0.023
3 Emerging Technologies	**0.003**	**0.006**	**0.010**	**0.016**	**0.022**	**0.039**	**0.086**	**0.137**	**0.172**	**0.191**
Lighting R&D: Controls	0.000	0.000	0.001	0.001	0.002	0.003	0.005	0.007	0.009	0.010
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.017	0.028
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.001	0.001	0.002	0.002	0.005	0.014	0.015	0.008	0.005
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.009	0.012	0.008
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.001	0.001	0.002	0.005	0.006	0.003	0.001
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.000	0.001	0.002	0.010	0.023	0.028	0.016
Appliances & Emerging Tech R&D: HPWH	0.000	0.001	0.001	0.002	0.002	0.005	0.010	0.011	0.014	0.016
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.003	0.004
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.006	0.006	0.006
Appliances & Emerging Tech R&D: R-Lamp	0.000	0.001	0.002	0.004	0.005	0.006	0.001	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.001	0.001	0.002	0.003	0.003	0.005	0.007	0.010	0.014	0.018
Window Technologies: Superwindows	0.001	0.001	0.002	0.003	0.004	0.006	0.016	0.025	0.036	0.048
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.004
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.005	0.008	0.011
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.006	0.011	0.015
4 Equipment Standards and Analysis	**0.000**	**0.001**	**0.001**	**0.002**	**0.007**	**0.016**	**0.041**	**0.063**	**0.073**	**0.083**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.005	0.007
Standards: EPAct Standards	0.000	0.001	0.001	0.002	0.005	0.011	0.027	0.041	0.047	0.053
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.002	0.005	0.012	0.019	0.021	0.023
Building Technologies Total	**0.003**	**0.007**	**0.011**	**0.019**	**0.030**	**0.060**	**0.151**	**0.246**	**0.315**	**0.372**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.12. CO Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.003**	**0.005**	**0.007**
Research & Development (Building America)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002
Zero Energy Buildings	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.005
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**	**0.004**	**0.006**	**0.008**
Research & Development	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.004	0.005
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
3 Emerging Technologies	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.005**	**0.013**	**0.021**	**0.026**	**0.030**
Lighting R&D: Controls	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.002	0.001
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.002
Appliances & Emerging Tech R&D: HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Appliances & Emerging Tech R&D: R-Lamp	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Window Technologies: Superwindows	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.005	0.007	0.009
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002
4 Equipment Standards and Analysis	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.002**	**0.005**	**0.008**	**0.010**	**0.011**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002
Standards: EPAct Standards	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.005	0.006	0.007
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003
Building Technologies Total	**0.000**	**0.001**	**0.002**	**0.002**	**0.004**	**0.007**	**0.021**	**0.036**	**0.047**	**0.056**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.13. PM Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**
Research & Development (Building America)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zero Energy Buildings	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**
Research & Development	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3 Emerging Technologies	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.004**	**0.005**	**0.005**
Lighting R&D: Controls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Appliances & Emerging Tech R&D: HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: R-Lamp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Window Technologies: Superwindows	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Equipment Standards and Analysis	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.002**	**0.003**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Standards: EPAct Standards	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Building Technologies Total	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.004**	**0.007**	**0.009**	**0.011**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.14. VOC Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**
Research & Development (Building America)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zero Energy Buildings	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**
Research & Development	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Emerging Technologies	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**
Lighting R&D: Controls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: R-Lamp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Window Technologies: Superwindows	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Equipment Standards and Analysis	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.001**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Standards: EPAct Standards	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Building Technologies Total	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.002**	**0.004**	**0.005**	**0.006**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.15. Consumer (Energy) Cost Savings (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**$4**	**$11**	**$25**	**$41**	**$64**	**$137**	**$459**	**$972**	**$1,655**	**$2,523**
Research & Development (Building America)	$2	$6	$14	$23	$36	$67	$131	$166	$185	$203
Residential Building Energy Codes	$0	$0	$0	$0	$1	$6	$72	$199	$340	$491
Zero Energy Buildings	$2	$5	$11	$18	$28	$64	$256	$607	$1,130	$1,828
2 Commercial Buildings Integration	**$0**	**$3**	**$6**	**$9**	**$18**	**$78**	**$724**	**$1,397**	**$2,047**	**$2,708**
Research & Development	$0	$3	$6	$9	$18	$72	$619	$1,041	$1,346	$1,648
Commercial Building Energy Codes	$0	$0	$0	$0	$0	$6	$106	$356	$702	$1,061
3 Emerging Technologies	**$135**	**$258**	**$431**	**$655**	**$939**	**$1,737**	**$4,340**	**$7,347**	**$9,207**	**$10,290**
Lighting R&D: Controls	$9	$16	$26	$38	$55	$98	$225	$312	$400	$483
Lighting R&D: Next Generation Lighting	$0	$0	$0	$0	$0	$0	$0	$350	$778	$1,302
Refrigeration R&D: Res. HVAC Dist. System	$11	$27	$49	$81	$125	$263	$787	$884	$487	$314
Refrigeration R&D: Adv. Elec HPWH	$0	$1	$2	$5	$10	$29	$193	$514	$654	$419
Refrigeration R&D: Commercial Refrigeration	$2	$6	$11	$18	$28	$60	$213	$266	$126	$25
Refrigeration R&D: Refrigerant Meter	$0	$2	$6	$14	$27	$78	$463	$1,218	$1,505	$892
Appliances & Emerging Tech R&D: HPWH	$15	$24	$39	$62	$93	$203	$505	$626	$763	$919
Appliances & Emerging Tech R&D: Roof Top AC	$0	$4	$7	$10	$12	$16	$22	$26	$31	$37
Appliances & Emerging Tech R&D: Gas Condensing WH	$0	$1	$4	$8	$14	$46	$135	$166	$197	$231
Appliances & Emerging Tech R&D: Recessed Can Lights	$0	$2	$6	$15	$29	$80	$254	$325	$327	$330
Appliances & Emerging Tech R&D: R-Lamp	$18	$47	$90	$143	$194	$277	$29	$0	$0	$0
Window Technologies: Electrochromic Windows	$40	$56	$75	$92	$113	$162	$286	$448	$629	$833
Window Technologies: Superwindows	$38	$66	$100	$143	$197	$339	$910	$1,492	$2,129	$2,833
Thermal Insulation: Quick Fill Walls	$0	$1	$1	$1	$2	$4	$16	$36	$60	$85
Thermal Insulation: R30 Insulation/30 Year Life Roofs	$0	$0	$0	$0	$0	$2	$26	$85	$149	$217
Thermal Insulation: Moisture/Wet Insulation	$1	$5	$11	$18	$28	$55	$150	$298	$463	$646
Analysis Tools and Design	$1	$2	$4	$6	$10	$24	$129	$302	$510	$723
4 Equipment Standards and Analysis	**$0**	**$22**	**$44**	**$64**	**$230**	**$606**	**$1,722**	**$2,938**	**$3,442**	**$3,981**
Standards: Res. Gas Furnaces/Boilers	$0	$0	$0	$0	$0	$31	$112	$202	$299	$407
Standards: EPAct Standards	$0	$22	$44	$64	$170	$399	$1,112	$1,866	$2,173	$2,493
Standards: Distribution Transformers	$0	$0	$0	$0	$60	$177	$498	$870	$969	$1,081
Building Technologies Total	**$139**	**$294**	**$505**	**$769**	**$1,251**	**$2,558**	**$7,245**	**$12,654**	**$16,351**	**$19,502**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.16. Non-Energy Cost Savings (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Research & Development (Building America)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Residential Building Energy Codes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Zero Energy Buildings	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2 Commercial Buildings Integration	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Research & Development	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Commercial Building Energy Codes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3 Emerging Technologies	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Lighting R&D: Controls	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Lighting R&D: Next Generation Lighting	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Refrigeration R&D: Res. HVAC Dist. System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Refrigeration R&D: Adv. Elec HPWH	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Refrigeration R&D: Commercial Refrigeration	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Refrigeration R&D: Refrigerant Meter	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: HPWH	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: Roof Top AC	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: Gas Condensing WH	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: Recessed Can Lights	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: R-Lamp	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Window Technologies: Electrochromic Windows	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Window Technologies: Superwindows	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Thermal Insulation: Quick Fill Walls	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Thermal Insulation: R30 Insulation/30 Year Life Roofs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Thermal Insulation: Moisture/Wet Insulation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Analysis Tools and Design	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4 Equipment Standards and Analysis	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Standards: Res. Gas Furnaces/Boilers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Standards: EPAct Standards	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Standards: Distribution Transformers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Building Technologies Total	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.17. Incremental Private Investment (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**$59**	**$95**	**$148**	**$172**	**$225**	**$304**	**$436**	**$576**	**$769**	**$928**
Research & Development (Building America)	$27	$48	$84	$87	$113	$128	$74	$27	$27	$27
Residential Building Energy Codes	$0	$0	$0	$0	$3	$18	$100	$136	$145	$155
Zero Energy Buildings	$31	$47	$64	$84	$110	$158	$262	$414	$597	$746
2 Commercial Buildings Integration	**$0**	**$0**	**$0**	**$0**	**$0**	**$22**	**$169**	**$300**	**$354**	**$428**
Research & Development	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Commercial Building Energy Codes	$0	$0	$0	$0	$0	$22	$169	$300	$354	$428
3 Emerging Technologies	**$708**	**$849**	**$1,061**	**$1,303**	**$1,668**	**$2,439**	**$3,790**	**$3,349**	**$3,896**	**$4,041**
Lighting R&D: Controls	$35	$28	$39	$50	$67	$92	$89	$57	$68	$65
Lighting R&D: Next Generation Lighting	$0	$0	$0	$0	$0	$0	$1	$32	$66	$104
Refrigeration R&D: Res. HVAC Dist. System	$2	$5	$9	$14	$21	$42	$136	$248	$300	$314
Refrigeration R&D: Adv. Elec HPWH	$0	$2	$4	$7	$12	$27	$126	$180	$119	$27
Refrigeration R&D: Commercial Refrigeration	$7	$10	$15	$21	$30	$56	$92	-$22	-$100	$-33
Refrigeration R&D: Refrigerant Meter	$0	$5	$12	$22	$37	$85	$353	$498	$263	$56
Appliances & Emerging Tech R&D: HPWH	$34	$22	$34	$50	$68	$135	$89	$92	$95	$98
Appliances & Emerging Tech R&D: Roof Top AC	$0	$14	$11	$10	$10	$9	$9	$8	$8	$8
Appliances & Emerging Tech R&D: Gas Condensing WH	$0	$3	$5	$7	$12	$22	-$1	$0	$2	$3
Appliances & Emerging Tech R&D: Recessed Can Lights	$2	$8	$18	$33	$54	$83	$76	-$43	-$46	$-49
Appliances & Emerging Tech R&D: R-Lamp	$11	$13	$11	$4	$6	-$26	-$69	-$79	-$81	$-82
Window Technologies: Electrochromic Windows	$141	$157	$190	$177	$206	$260	$235	$343	$381	$426
Window Technologies: Superwindows	$463	$557	$678	$857	$1,078	$1,564	$2,480	$1,836	$2,605	$2,865
Thermal Insulation: Quick Fill Walls	$0	$1	$0	$1	$2	$3	$10	$14	$14	$16
Thermal Insulation: R30 Insulation/30 Year Life Roofs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Thermal Insulation: Moisture/Wet Insulation	$13	$24	$34	$50	$66	$88	$164	$184	$204	$221
Analysis Tools and Design	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4 Equipment Standards and Analysis	**$0**	**$198**	**$205**	**$189**	**$1,568**	**$1,646**	**$2,010**	**$2,213**	**$787**	**$838**
Standards: Res. Gas Furnaces/Boilers	$0	$0	$0	$0	$0	$25	$8	$6	$3	$0
Standards: EPAct Standards	$0	$198	$205	$189	$971	$1,036	$1,332	$1,424	$575	$607
Standards: Distribution Transformers	$0	$0	$0	$0	$597	$584	$669	$783	$210	$231
Building Technologies Total	**$766**	**$1,142**	**$1,414**	**$1,664**	**$3,461**	**$4,411**	**$6,405**	**$6,438**	**$5,806**	**$6,234**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.18. Employment Impacts, Savings Only (Thousand Jobs/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.1**	**0.1**	**0.2**	**0.3**	**0.5**	**1.1**	**3.7**	**7.9**	**13.6**	**20.9**
Research & Development (Building America)	0.0	0.1	0.1	0.2	0.3	0.5	1.0	1.3	1.4	1.6
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.4	2.3	3.4
Zero Energy Buildings	0.0	0.1	0.1	0.2	0.3	0.6	2.2	5.3	9.8	15.9
2 Commercial Buildings Integration	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.5**	**4.9**	**10.3**	**16.3**	**22.5**
Research & Development	0.0	0.0	0.0	0.1	0.1	0.4	3.8	6.6	9.0	11.4
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.1	1.1	3.7	7.3	11.1
3 Emerging Technologies	**1.9**	**2.4**	**3.9**	**6.0**	**8.5**	**15.6**	**37.9**	**65.3**	**82.3**	**90.7**
Lighting R&D: Controls	0.1	0.2	0.3	0.4	0.6	1.0	2.3	3.2	4.1	5.0
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	8.0	13.4
Refrigeration R&D: Res. HVAC Dist. System	0.1	0.2	0.4	0.6	0.9	2.0	5.9	6.7	3.7	2.5
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.0	0.1	0.1	0.3	1.9	4.9	6.2	4.0
Refrigeration R&D: Commercial Refrigeration	0.0	0.1	0.1	0.2	0.3	0.6	2.1	2.7	1.3	0.3
Refrigeration R&D: Refrigerant Meter	0.0	0.0	0.1	0.2	0.3	0.8	4.8	12.5	15.5	9.2
Appliances & Emerging Tech R&D: HPWH	0.2	0.3	0.4	0.6	1.0	2.1	5.2	6.4	7.8	9.4
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.0	0.0	0.0	0.1	0.2	0.7	0.8	1.0	1.1
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.0	0.1	0.2	0.3	0.8	2.6	3.3	3.4	3.4
Appliances & Emerging Tech R&D: R-Lamp	0.3	0.5	0.9	1.5	2.0	2.9	0.3	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	0.7	0.6	0.8	1.0	1.2	1.8	3.1	4.7	6.6	8.7
Window Technologies: Superwindows	0.4	0.5	0.7	1.0	1.4	2.5	6.6	10.9	15.7	21.0
Thermal Insulation: Quick Fill Walls	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.5
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.9	1.3
Thermal Insulation: Moisture/Wet Insulation	0.0	0.0	0.1	0.1	0.2	0.3	0.8	1.7	2.8	3.9
Analysis Tools and Design	0.0	0.0	0.0	0.1	0.1	0.2	1.2	2.8	4.7	6.7
4 Equipment Standards and Analysis	**0.0**	**0.2**	**0.5**	**0.7**	**2.4**	**6.0**	**16.9**	**28.8**	**33.3**	**38.1**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	0.2	0.5	1.0	1.4	1.9
Standards: EPAct Standards	0.0	0.2	0.5	0.7	1.7	4.0	11.2	18.9	21.9	25.0
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	0.6	1.8	5.1	9.0	10.0	11.2
Building Technologies Total	**2.0**	**2.7**	**4.6**	**7.0**	**11.5**	**23.2**	**63.4**	**112.4**	**145.6**	**172.2**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.19. Income Impacts, Savings Only (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**$0**	**$1**	**$1**	**$2**	**$3**	**$7**	**$25**	**$54**	**$95**	**$150**
Research & Development (Building America)	$0	$0	$1	$1	$1	$2	$5	$7	$8	$9
Residential Building Energy Codes	$0	$0	$0	$0	$0	$0	$1	$2	$4	$7
Zero Energy Buildings	$0	$0	$1	$1	$2	$5	$19	$44	$83	$134
2 Commercial Buildings Integration	**$0**	**$0**	**$1**	**$1**	**$2**	**$8**	**$78**	**$172**	**$278**	**$386**
Research & Development	$0	$0	$1	$1	$2	$7	$58	$105	$144	$184
Commercial Building Energy Codes	$0	$0	$0	$0	$0	$1	$20	$68	$134	$202
3 Emerging Technologies	**$21**	**$28**	**$45**	**$67**	**$93**	**$165**	**$384**	**$713**	**$932**	**$1,026**
Lighting R&D: Controls	$2	$3	$5	$7	$10	$18	$42	$58	$75	$90
Lighting R&D: Next Generation Lighting	$0	$0	$0	$0	$0	$0	$0	$65	$145	$243
Refrigeration R&D: Res. HVAC Dist. System	$1	$1	$2	$3	$4	$8	$26	$30	$19	$15
Refrigeration R&D: Adv. Elec HPWH	$0	$0	$0	$1	$1	$3	$23	$60	$76	$48
Refrigeration R&D: Commercial Refrigeration	$1	$1	$2	$3	$5	$11	$38	$47	$22	$4
Refrigeration R&D: Refrigerant Meter	$0	$0	$1	$2	$4	$11	$64	$168	$207	$123
Appliances & Emerging Tech R&D: HPWH	$2	$3	$5	$8	$12	$25	$63	$78	$95	$115
Appliances & Emerging Tech R&D: Roof Top AC	$0	$1	$1	$2	$2	$3	$4	$5	$6	$7
Appliances & Emerging Tech R&D: Gas Condensing WH	$0	$0	$0	$0	-$1	-$3	-$8	-$10	-$11	$-13
Appliances & Emerging Tech R&D: Recessed Can Lights	$0	$0	$1	$2	$4	$10	$32	$41	$41	$41
Appliances & Emerging Tech R&D: R-Lamp	$3	$6	$11	$18	$24	$35	$4	$0	$0	$0
Window Technologies: Electrochromic Windows	$10	$12	$16	$19	$23	$33	$57	$87	$121	$159
Window Technologies: Superwindows	$2	$1	$2	$3	$5	$8	$25	$41	$62	$87
Thermal Insulation: Quick Fill Walls	$0	$0	$0	$0	$0	$0	$0	$0	$0	$-1
Thermal Insulation: R30 Insulation/30 Year Life Roofs	$0	$0	$0	$0	$0	$0	$1	$3	$6	$8
Thermal Insulation: Moisture/Wet Insulation	$0	$0	-$1	-$1	-$1	-$2	-$4	-$7	-$9	$-11
Analysis Tools and Design	$0	$0	$1	$1	$2	$4	$20	$46	$78	$110
4 Equipment Standards and Analysis	**$0**	**$4**	**$8**	**$12**	**$42**	**$103**	**$286**	**$485**	**$551**	**$620**
Standards: Res. Gas Furnaces/Boilers	$0	$0	$0	$0	$0	-$2	-$7	-$12	-$18	$-24
Standards: EPAct Standards	$0	$4	$8	$12	$31	$72	$200	$335	$387	$442
Standards: Distribution Transformers	$0	$0	$0	$0	$11	$33	$93	$162	$181	$202
Building Technologies Total	**$21**	**$33**	**$55**	**$82**	**$140**	**$282**	**$773**	**$1,424**	**$1,855**	**$2,182**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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A.3 Residential Technology R&D

Residential Buildings Integration Decision Unit

Project Objective:[1]

The Residential Technology R&D project consolidates the formerly separate systems engineering projects of Building America, Industrialized Housing, Passive Solar Buildings, and Indoor Air Quality and existing building research into a comprehensive project to accelerate the introduction of highly efficient building technologies and practices through R&D of advanced systems for builders.

Long-Term Goal:[1]

The project's long-term goal is to develop advanced systems to improve the energy performance of over 300,000 homes by 2010. The increased performance will allow the homes to use 50% less energy for space conditioning and water heating than typical homes built in 1993.

Market Segment:

Performance Objective:[2]

- **Displaced Technology:** Current design/building practices.
- **Performance Target:** 50% load reduction in space heating and cooling and water heating by 2010.

Target Market[1]

- **Market Description:** The market includes new single-family, multifamily, and manufactured housing units in all climate zones. The market includes primarily new single-family homes, multifamily infill, HUD code homes, and small commercial buildings. Existing homes would also indirectly benefit from new technologies and improved construction practices developed for new homes.
- **Size of Market:** Each year ~1.2 million new housing units are built. These units are primarily owner occupied.
- **Market Introduction:** 1997[2]; this activity was assumed not to occur without DOE funding; therefore, the National Research Council (acceleration-to-market) methodology was not applied.
- **Market Penetration Goal:**[3] See Table A- 3.1.

Residential Technology R&D

Project Type:
Whole building

Target Market:
New single-family, multifamily, and manufactured housing units with homeowners in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
% change in load per household

Modeling Tool:
BESET

Project Manager:
George James/Jon Stone

Website:
http://www.eren.doe.gov/buildings/building_america

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.3	0.9	9.1	21.0

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.005	0.015	0.157	0.352

Consumer Cost Savings (million $):

2004	2005	2010	2020
2	6	67	166

A.3 Residential Technology R&D

Residential Buildings Integration Decision Unit

Table A-3.1. FY 2004 Market Penetration for Residential Technology R&D Projects

Year	Annual # Homes
2004	10,800
2005	18,900
2006	33,075
2007	34,729
2008	44,762
2009	47,000
2010	50,916
2011	50,916
2012	45,825
2013	35,132
2014	30,916
2015	29,216
2016	26,795
2017	23,669
2018	19,882
2019	15,508
2020	10,649

Methodology

For any one year, the project's energy savings are calculated by multiplying the number of homes built with Building America techniques that year times the percent savings per home. Added to this are the energy savings, in that year, for Building America homes built in previous years (within the analysis period, any savings resulting from homes built before 2004 are not included).

Project/Technology Consumer Costs:

- Cost of Conventional Technology (average price per household)[4]:
  - Single Family: $126,700
  - Multifamily: $74,900
  - Manufactured Home: $41,100.
- Cost of BTS Technology:[5] 2% above conventional cost.
- Incremental Cost (average price per household):
  - Single Family: $2,534
  - Multifamily: $1,498
  - Manufactured Home: $822.

Non-Energy Benefits:[1]

- Consumer savings of $148 million by 2010
- Improved comfort, durability, and occupant health from better indoor air quality
- Reduced onsite generated waste

- Better sustainability
- Reduced maintenance.

Sources:

(1) FY 2002 Budget – *Data Bucket Report for Residential Building Integration R&D Program* (internal BT document).
(2) *FY 2002 GPRA Program Characterization* (internal BT document).
(3) Based on Impacts spreadsheet developed by Ren Anderson, ORNL, August 10, 2000.
(4) Average prices for single-family and multifamily homes are based on information from *MEANS Square Foot Cost 1995* and from Table 3.1b in "Residential Energy Consumption Survey." 1997. U.S. Department of Energy, Energy Information Administration. eia.doc.gov/emeu/recs/contents.html. Average prices for manufactured housing derived from data provided by the Manufactured Housing Institute, "Manufactured Home Shipments, Estimated Retail Sales and Average Sales Prices" (1997).
(5) *GPRA Metrics for the FY2000 Budget Request: Data Collection Survey*, August, 1998 (internal PNNL document).

A.4 Residential Building Codes

Residential Buildings Integration Decision Unit

Project Objective:[1]

The Residential Building Codes activity, as part of the larger Building Energy Codes project, improves the minimum or baseline energy efficiency of new residential buildings requiring code permits. The project promulgates upgraded energy-efficiency requirements for residential buildings. Similarly, the project works with model energy code groups to upgrade the energy-efficiency requirements of their codes. Federal, state, and local jurisdictions then adopt and implement these upgraded federal and model energy codes (see the Gateway Deployment decision unit within WIP [Appendix B]).

Long-Term Goal:[2]

The project's long-term goal is to improve the minimum energy efficiency by 20% to 25% in new low-rise residential building construction.

Market Segment:

Target Market[1]

- Market Description: The market includes new residential low-rise buildings three stories or less in height and additions and alterations to existing buildings requiring code permits. (See the Commercial Building Integration decision unit in this appendix for high-rise residential buildings.)

  The project can affect residences major energy end uses, including heating, cooling, water heating, and possibly lighting energy in the near future. All areas of the country are affected because the model building codes and standards cover all climate zones. Household income is not a discrimination of the target market because building codes cover housing at all costs and income levels. Energy-efficiency improvements through codes have repeatedly demonstrated a net positive cash flow to the new home buyer within five years, thereby actually improving household income. The savings from improved appliances and equipment are not included in this project's savings estimates because they are reflected in the Equipment Standards and Analysis decision unit in this appendix. Heating and cooling distribution systems are included in this project.

Residential Building Codes

Project Type:
Regulatory

Target Market:
New residential buildings in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
% load reduction

Modeling Tool:
Spreadsheet

Project Manager:
Steve Walder

Website:
http://www.energycodes.gov

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FY2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.0	0.0	0.8	26.8

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.000	0.000	0.014	0.437

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	0	6	199

A.4 Residential Building Codes

Residential Buildings Integration Decision Unit

Energy savings from this project and from the related Building Energy Codes activities in the Gateway Deployment decision unit result from some basic improvements in overall energy efficiency of commercial buildings. The present funding for conducting research activities for new residential low-rise energy codes is through the Residential Buildings decision unit. Funding for developing core materials (such as compliance tools and training materials) and providing training and financial and technical assistance for states to update and implement their building energy codes is through the Gateway Deployment decision unit. Benefits cannot be clearly allocated to either decision unit.

- **Size of Market:** Each year ~1.4 million building permits are issued, over a million for single-family dwellings. Although not all jurisdictions currently have energy-efficiency building codes in place, about half of all new residential construction is conservatively estimated to come under building energy code requirements. Also, consumers spend several billion dollars a year remodeling and renovating projects in private residences, about half of which could presently be covered by an energy code. One market not currently covered by codes is manufactured homes, which fall under HUD jurisdiction and regulations.

Methodology

The FY 2004 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 2001 and 2003 editions of the International Energy Conservation Code (IECC) code (to comply with Section 304 of the Energy Conservation and Production Act), and the future development of more stringent building codes. The energy savings methodology was applied at a state level to better link changes in the national codes (e.g., IECC 2003) with variations in climate by states and differences among states in their adoption and enforcement of building codes. The discussion below uses national averages of some of the key assumptions related to adoption and compliance to help summarize the methodology.

The principal difference between the 1995 Model Energy Code and the IECC 2001 involves the solar heat gain requirements for windows and increased thermal resistance requirements for ducts in unconditioned spaces. Based on a series of simulations for various U.S. locations, the percentage reduction in cooling load was estimated to be ~15%. This requirement increases the heating load by a small amount, ~2% nationally. (The requirement itself is restricted to the southern tier of states). The GPRA estimates were partly based on states' accelerated schedule of adoption of the IECC 2001 and 2003 codes. Through the efforts of the Building Energy Codes project, 31 states were assumed to have adopted the standard by the end of 2005. The project was assumed to accelerate the adoption of the standard by an average of four years nationwide.

The IECC's ongoing activities were assumed to lead to more stringent residential standards in the future. DOE was assumed to play a major role in developing the analytical and economic basis for such standards. For the GPRA process, these activities were subsumed in a single upgrade of the IECC standard assumed to become available in the latter part of the current decade. Based on discussions with BT staff, PNNL assumed that the results of these upgrades were to reduce heating and cooling loads in new residential structures by 10%. Without these activities, the analysis assumed that the same standard would be adopted, on average, six years later.

A.4 Residential Building Codes

Residential Buildings Integration Decision Unit

The project's activities also were assumed to improve compliance rates for codes currently adopted by states and localities as well as future building codes. Compliance is increased through better familiarity with the codes over time, simplifications to the code while maintaining stringency, and the availability and increased use of compliance tools by builders and enforcement officials. Compliance rates, with and without the project, were estimated for various standards as discussed above. As a national average, compliance with existing codes was estimated at 45% in 2003, rising to 49% without the project and 72% by 2010 with the project.

The compliance with the several key provisions in the IECC 2000 and 2003 (compared with the 1995 Model Energy Code) was expected to be higher from the outset. On average, the compliance was estimated to be 68% in the year of the adoption. By 2010, compliance rates were assumed to increase to 69% without the project and 74% with the project. For homes that do not comply with the standard, only half of the incremental energy savings were assumed to be achieved by adopting IECC 2001 or 2003.

The analysis assumed that when states first adopt the new standard assumed to become available in the 2006-2007 timeframe, the standard's greater stringency will result in somewhat lower compliance. Initial compliance was assumed to be ~30% at the time of adoption, increasing to 31% without the project and 73% with the project after the first ten years. For IECC 2001 and 2003, the energy savings in units that do not comply were assumed to be 50% of that in units that comply fully with the code.

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 5-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $5).

Non-Energy Benefits:[2]

- Lower utility bills
- Improved indoor comfort
- Lower home maintenance and repair activities
- Reduced pollution from with burning fossil fuels and generating electricity, which improves air quality and mitigates the negative impacts of global warming.

Project Strategy (% of budget):[2]

- Research and Development – 0%
- Market Transformation – 0%
- Codes and Standards – 100%.

Sources:

(1) FY 2004 data collection input provided by Jean Boulin, BT/WIP, May, 2002.

A.4 Residential Building Codes

Residential Buildings Integration Decision Unit

(2) FY 2002 Budget – *Data Bucket Report for Residential Buildings Integration R&D Program* (internal BT document).

A.5 Zero Energy Buildings

Residential Buildings Integration Decision Unit

Project Objective:[1]

U.S. buildings are responsible for 35 quads of energy usage, or 36% of the country's total consumption. This fraction places buildings on a par with industry (also 36%) as a critical element in the effort to improve the country's energy security. A large portion of the energy consumed in buildings is electrical; 67% of every kilowatt-hour sold is for a building application. Electricity demand is divided almost equally between residences (35%) and commercial buildings (32%). Given the enormity of the building sector's energy impact, DOE established the Zero Energy Buildings (ZEB) project to dramatically reduce building energy consumption. The long-term objective of ZEB is to produce a home that uses zero net fossil energy over the course of a year.

Long-Term Goal:[1]

The project's long-term goal is to achieve, through optimal integration of energy efficiency and site generation, sufficient technology advances to enable the following:

- 50% of U.S. housing to be constructed as affordable zero net energy homes by 2010.
- 50% of U.S. commercial buildings to be constructed as, or converted to, affordable zero net energy buildings by 2015.

Market Segment:

Target Market

- **Market Description:**[2] The market includes new single-family homes. The primary market will be homes constructed in climate zones 4 and 5 (southern U.S.). Further, project construction techniques are likely to be adopted primarily by builders of housing developments where subdivision loads can be aggregated for electric utilities. For analytical purposes, this market consists of the top 200 single-family developers (each of these builders built a minimum of 215 new homes in 2001).
- **Size of Market:** Each year ~1.2 million new housing units are built. These units are primarily owner occupied. The top 200 builders built over 350,000 of those homes in 2001 (or ~30%).[3]
- **Market Introduction:** The technology to construct a zero net energy home currently exists; however, penetration into the general market is expected to continue to be extremely low without DOE funding because the technology is currently unaffordable for production home

Zero Energy Buildings Project

Project Type:
Whole building

Target Market:
Residential

End Uses:
All end uses, all fuel types

Unit of Measurement:
% energy consumption reduction

Modeling Tool:
Spreadsheet

Project Manager:
Lew Pratsch

Website:
http://www.eren.doe.gov/solarbuildings

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FY 2004 Benefits

Primary Energy Savings (TBtu)

2004	2005	2010	2020
0.3	0.8	8.3	71.6

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.005	0.013	0.155	1.280

Consumer Cost Savings (million $)

2004	2005	2010	2020
2	5	64	607

A.5 Zero Energy Buildings

Residential Buildings Integration Decision Unit

builders. Therefore, the National Research Council (acceleration-to-market) methodology was not applied.

- **Market Penetration Goal:**[2,4,5] Of the homes built by the top 200 builders, at least 20% of new high-end homes in the climate zones 4 and 5 would be ZEB by 2010 (a "high-end" home is defined as having an owner with an annual household income >$50,000). This proportion increases to 50% by 2020. Further goals are to build 20% of "middle" homes (owner's annual household income from $25,000 to $50,000) as ZEB by 2020 and to build 20% of low-end homes (owner's annual household income is <$25,000) as ZEB by 2030.

Performance Objective:[2]

- **Displaced Technology:** The project displaces current design/building practices.
- **Performance Target:** The performance target for this project is for houses to have $50/month utility bill by 2004; a $1/day utility bill by 2007; and a 67% load reduction, with remainder of building load to be met by photovoltaics ($0 utility bill), by 2010.

Methodology

For any given year, energy savings for this project are calculated by multiplying the number of homes built with ZEB techniques that year times the percent savings per home. Added to this are the energy savings, in that year, for ZEB homes built in previous years (any savings resulting from homes built before 2004 are not included).

Performance targets were translated into energy consumption reductions by calculating the difference between the average annual energy expenditure per household ($1,295)[6] and the target utility bill, yielding reductions of 54% in 2004, 72% in 2007, and 100% in 2010. Annual delivered energy consumption was assumed to be 100.2 million Btu[7].

The target market was defined as homes built by the top 200 builders, who currently are responsible for building ~30% of all single-family homes each year. Consolidation in the home-building industry was assumed to increase the share of these builders to 40% by 2020 and to 50% by 2030. This market was further refined to reflect the owner's household income level because ZEB homes will initially be targeting the higher-end housing market, followed by middle- and low-end homes. Based on the RECS 1997[8] data for occupied homes constructed in the 1990-1997 period, it was assumed that high-end homes would be represented by those with an annual household income of $50,000 or more (40% of homes); middle-income homes are represented by an annual household income of $25,000 to $49,999 (31% of homes); and low-end homes are represented by an annual household income <$25,000 (29% of homes).[9]

The fundamental premise leading to wide adoption is that existing technologies and projects will eventually reduce energy use by ~67% and reduce summer peak loads to zero. This, in turn, will result significantly in less photovoltaic technology needed to supply the home's load while shaving summer peak loads and pressure to expand the grid to accommodate peak load growth. With much improved load characteristics, ZEB houses in 2004 to 2007 are expected to receive slightly lower electric rates and by 2010 will have a zero electric bill in return for zero summer peak loads.

A.5 Zero Energy Buildings

Residential Buildings Integration Decision Unit

Estimates do not include potential applications to manufactured homes or in commercial buildings – both stated project goals. Zero energy homes were assumed to only be likely to penetrate the well-organized, well-trained, subdivision developer market. These developers are assumed to be more likely to negotiate for favorable electrical service with local utilities – based on the ZEB concept. Energy savings resulting from adoption by smaller spec builders and one-off builders are not captured but could be significant if utilities offer a "ZEB" rate to all homeowners.

Project/Technology Consumer Costs:

- **Cost of Conventional Technology** (average price per household): Single-Family — $210,000. The single-family home price is the 1999 average unit price of homes built by the five largest builders in the U.S.[10]
- **Incremental Cost of BTS Technology:** Single Family — Initially, modeled as a 5% cost increase over conventional prices (or $10,500)[2] through 2010. Then, because the affordability goal is to have incremental costs no more than five times the average annual energy cost, the incremental cost was modeled to drop to $6,475 in 2015 (five times the average annual energy cost of $1,295).[1]

Non-Energy Benefits:

- Improved comfort in the home resulting from advanced envelope, HVAC designs, and automated energy management systems.[5]

Sources:

(1) Pratsch, L., and J. Talbott. May 1, 2002 (Draft). "Technology Pathways for the DOE Zero Energy Buildings Program," Office of Technology Development Buildings Program, Washington, D.C.

(2) Information obtained in a discussion with the project manager, Lew Pratsch, June 20, 2002.

(3) "The BUILDER 100 Database" and "The Next 100" at www.builderonline.com.

(4) Information obtained in a discussion with the project manager, Lew Pratsch, July 11, 2002.

(5) Information obtained in a discussion with the project manager, Lew Pratsch, July 17, 2002.

(6) BTS Core Databook (July 13, 2002), Table 4.2.5, "Average annual energy expenditure for homes constructed in 1996-1997."

(7) BTS Core Databook (July 13, 2002), Table 1.2.6, "Average delivered energy consumption for homes constructed in 1996-1997."

(8) "Residential Energy Consumption Survey." 1997. U.S. Department of Energy, Energy Information Administration, Washington, D.C. eia.doc.gov/emeu/recs/contents.html

(9) Table HC1-3a, "Housing Unit Characteristics by Household Income, Million U.S. Households, 1997," in "Residential Energy Consumption Survey." 1997. U.S. Department of Energy, Energy Information Administration, Washington, D.C. eia.doc.gov/emeu/recs/contents.html

(10) BTS Core Databook (July 13, 2002), Table 5.1.1, "2001 Five Largest Residential Homebuilders."

A.6 Commercial Buildings Technology R&D

Commercial Buildings Decision Unit

Project Objective:

The Commercial Buildings Technology R&D project develops and demonstrates advanced technologies, controls, and equipment in collaboration with the design and construction community. The project focuses on advancing integrated technologies and practices to optimize whole-building energy performance. The project reduces energy use in commercial and multifamily buildings by promoting practices that help ensure the industry constructs buildings as designed and operates them at or near the optimum level of performance.

Long-Term Goal:

The project's long-term goal is to improve the energy efficiency of the nation's new commercial buildings by 30% and existing buildings by 20% compared with buildings built in 1996.

Market Segment:

Performance Objective[1]

- **Displaced Technology:** The project displaces conventional design/ building practices.
- **Performance Target:**
  - By 2004 reduce heating and cooling loads by 30% in new construction and by 20% in existing units
  - By 2010 reduce heating and cooling loads by 50% in new construction and by 30% in existing units.
  - By 2020 reduce heating and cooling loads by 60% in new construction and 40% in existing units.

Target Market[1]

- **Market Description:** Although this project does not explicitly exclude any particular building type, the types of commercial buildings that will most likely be impacted by the technologies developed by this project include buildings with relatively higher energy use intensities such as assembly, education, food service, food sales, health care, lodging, mercantile and service, and office buildings.
- **Market Introduction:** 1996 (inception date of project is 1977). Products supported by this project were assumed not to be developed without DOE funding; therefore, the National Research Council (acceleration-to-market) methodology was not applied.

Commercial Buildings Technology R&D

Project Type:
Whole building

Target Market:
New and existing commercial and residential multifamily units in all climate zones

End Uses:
Heating and cooling

Unit of Measurement:
% change in load

Modeling Tool:
BESET

Project Manager:
Dru Crawley

Website:
http://www.eren.doe.gov/buildings/highperformance

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.0	0.5	10.9	140.6

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.000	0.009	0.201	2.501

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	3	72	1041

A.6 Commercial Buildings Technology R&D

Commercial Buildings Decision Unit

- **Market Penetration Goal:** The market penetration goal is to penetrate 60% of new commercial and multifamily construction by 2020 in combination with the Analysis Tools and Design Strategies project and to penetrate 20% of the existing commercial and multifamily buildings by 2020 (see Figure A-6.1).

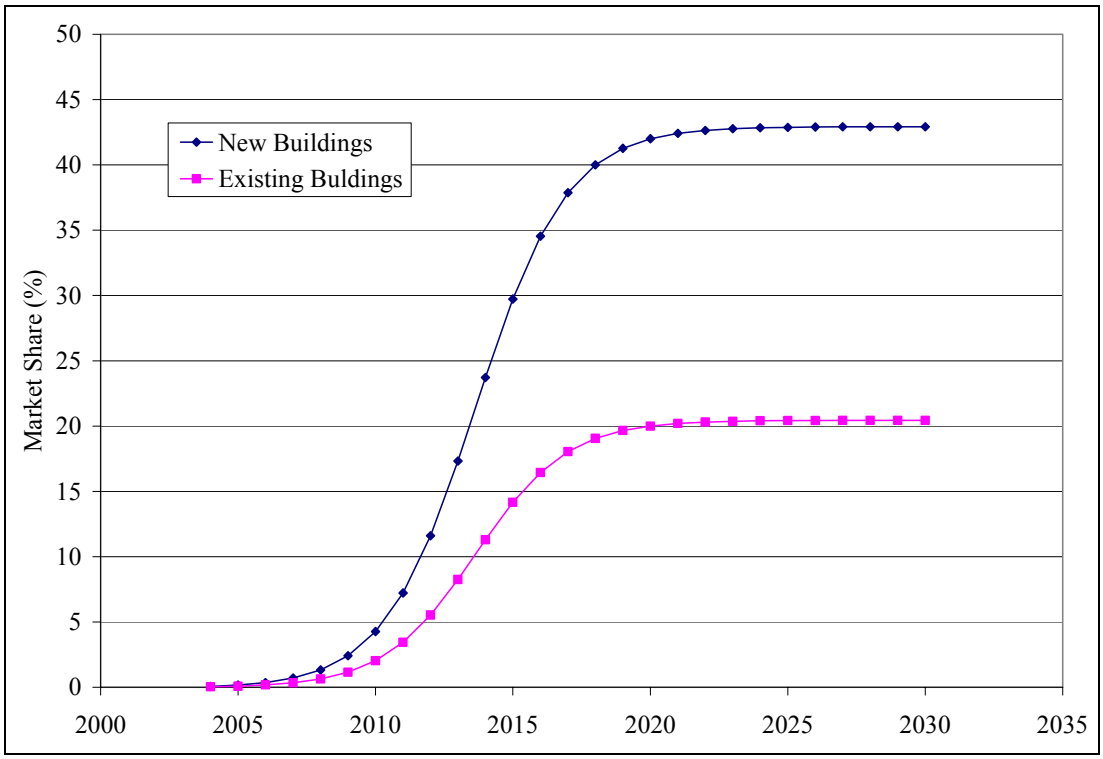

Figure A-6.1. Market Penetration Curve for Commercial Technology R&D Projects

Non-Energy Benefits:

- Reduced operation and maintenance expenses
- Improved indoor environmental quality
- Increased property asset value
- Higher tenant satisfaction and retention rates
- Increased technology sales.

Sources:

(1) Interview with the project manager, Dru Crawley, August, 2001.

A.7 Commercial Building Codes

Commercial Buildings Integration Decision Unit

Project Objective:[1]

The Commercial Building Codes activity, as part of the larger Building Energy Codes project, improves the minimum energy efficiency of new commercial and multifamily high-rise buildings and additions and alterations to existing buildings requiring code permits. The project promulgates upgraded energy-efficiency requirements for federal commercial and high-rise residential building types. Similarly, the project works with model energy code groups to upgrade the energy-efficiency requirements of their codes. These upgraded federal and Model Energy Codes are then adopted and implemented by federal, state, and local jurisdictions (see the Gateway Deployment decision unit within WIP [see Appendix B]).

Long-Term Goal:[1]

The project's long-term goal is to improve minimum energy efficiency by 30% to 35% in new commercial building construction. Energy use will be reduced by states and local jurisdictions widely adopting building energy codes.

Market Segment:

Target Market

- **Market Description:** The market includes all new commercial and multifamily high-rise buildings and all additions and renovations to buildings requiring code permits.
- **Size of Market:** The market size is ~2 billion ft^2 of new commercial floor space. The federal sector represents ~2.3% overall of new commercial building construction.

Methodology

Energy savings from this project and from the related building energy code activities in the Gateway Deployment decision unit (WIP) result from some basic improvements in the overall energy efficiency of commercial buildings. The present funding for conducting research activities for new commercial and multifamily high-rise energy codes is through the Commercial Buildings Integration decision unit. Funding for developing core materials (such as compliance tools and training materials) and providing training and financial and technical assistance for states to update and implement

Commercial Building Codes

Project Type:
Regulatory

Target Market:
New commercial buildings and additions and alterations to existing buildings in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
% change in load

Modeling Tool:
Spreadsheet

Project Manager:
Ron Majette

Website:
http://www.energycodes.gov

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.0	0.0	0.9	45.0

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.000	0.000	0.014	0.437

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	0	6	356

A.7 Commercial Building Codes

Commercial Buildings Integration Decision Unit

their building energy codes is through the Gateway Deployment decision unit. Benefits cannot be clearly allocated to either decision unit, thus the benefits estimated here are a function of both training and deployment as well as development of the commercial building energy codes and standards.

Barring future guidance from DOE, benefits for FY 2004 were assumed to be allocated according to the ratio of actual funding levels. The description of the methodology below also pertains to Training and Assistance for Codes project in Appendix B.

The project's impact is primarily through two avenues: 1) developing and supporting code changes to improve the minimum energy-efficiency requirements for commercial and multifamily high-rise buildings and 2) providing technical and financial assistance to states to update and implement their building energy codes. The latter includes developing tools that can ease the adoption of new codes and through their use, can support improvements in compliance and enforcement of code provisions. Tools take the form of code compliance software, computer-based training tools for building energy codes, and tools for implementing noncomputer-based codes.

Improvements to building codes are primarily supported by research efforts to review existing codes and specific targeted areas of building energy use and the adoption of code modifications that promote cost-effective reductions in these energy-use areas. Support for the research work has typically taken place in three areas:

- Upgrading ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings"[2]
- Ugrading the federal commercial and multifamily high rise building energy code, 10 CFR 434, "Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings"[3]
- Upgrading the International Energy Conservation Code (IECC).[4]

The FY 2004 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 1999 and 2002 editions of ASHRAE 90.1-1999[5] standard (to comply with Section 304 of the Energy Conservation and Production Act), and the future development of more stringent building energy codes. The energy savings methodology was applied at a state level to better link changes in the codes (e.g., IECC 2003) with variations in climates by states and differences among states in their adoption and enforcement of building codes. The discussion below uses national averages of some of the key assumptions related to adoption and compliance to help summarize the methodology, but appropriate state averages were used in the analysis.

The principal differences between the ASHRAE 90.1-1989, 90.1-1999, and 90.1-2002[6] standards relate to requirements for better windows, reduced installed wattage for lighting, and more efficient heating and cooling equipment. The savings from improved equipment are not included in the project's savings estimates because they are reflected in the Equipment Standards and Analysis decision unit in this appendix. Based on a series of simulations that include various U.S. locations and that were developed specifically to evaluate the two

A.7 Commercial Building Codes

Commercial Buildings Integration Decision Unit

ASHRAE standards (often referred to as the "determination" study[7]), the average reduction in site energy use was estimated to be ~3.5% or ~2 MMBtu/sq ft. The GPRA estimates were partly based on states' accelerated adoption schedule of the ASHRAE 90.1-1999 and 90.1-2002 standards. Through the efforts of the Building Energy Codes project, 35 states were assumed to have adopted the standard by the end of 2005. The project was assumed to accelerate the adoption of the standard by an average of four years nationwide.

The ongoing activities of the ASHRAE 90.1 committee were assumed to lead to more stringent commercial building standards in the future. DOE was assumed to play a major role in developing the analytical and economic basis for such standards. For the GPRA process, these activities were subsumed in a single upgrade of the ASHRAE standard assumed to become available in the latter part of the current decade. The GPRA analysis assumed that the overall result of these upgrades is to reduce electricity consumption by 10% and natural gas consumption by 2% in new commercial buildings. Many states adopting this standard by 2010 also depends on the project's continuing activities to assist states in the adoption (and compliance) process. Without these activities, the analysis assumed that the same standard would be adopted, on average, six years later.

The project activities were also assumed to improve compliance rates for codes currently adopted by states and localities as well as future building codes. Compliance is increased through increased familiarity with the codes over time, simplifications to the code while maintaining stringency, and the availability and increased use of compliance tools by builders and enforcement officials. Compliance rates, with and without the project, were estimated for the existing code, a code based on ASHRAE 90.1-1999, and a future standard as discussed above. On a national average basis, compliance with existing codes was estimated at 60% in 2000, rising to 66% without the project, and 79% by 2010 with the project.

The compliance with the several key provisions in ASHRAE 90.1-2001 (compared with 90.1-1999) was expected to be higher from the outset. On average, PNNL estimated the compliance to be 65% in the year of the adoption. Ten years later, compliance rates were assumed to increase to 67% without the project and 72% with the project. For buildings that do not comply with the standard, only half of the incremental energy savings were assumed to be achieved by adopting the ASHRAE 90.1-2001 standard.

The analysis assumed that the simplifications in the ASHRAE 90.1-1999 and 90.1-2001 standards will be extended to the new standard and will result in somewhat higher compliance when states first adopt them. Initial compliance was assumed to be ~27% at the time of adoption, rising to 31% without the project and 73% with the project after the first ten years. The energy savings in buildings that do not comply with the new standards were assumed to be 65% of that in buildings that comply fully with the code.

A.7 Commercial Building Codes

Commercial Buildings Integration Decision Unit

Project/Technology Consumer Costs (PNNL Estimates):

- Incremental investment costs were developed assuming a 5-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $5).

Non-Energy Benefits:

- Improved environment and more comfortable buildings.

Sources:

(1) FY 2002 Budget – *Data Bucket Report for Commercial Buildings Codes Program* (internal BT document).
(2) ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers and Illuminating Engineering Society.
(3) 10 CFR 434, "Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings," *Code of Federal Regulations*, as amended.
(4) International Energy Conservation Code. 2003. International Code Council, Falls Church, Virginia.
(5) ASHRAE/IES Standard 90.1-1999, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(6) ASHRAE/IES Standard 90.1-2002, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(7) U.S. Department of Energy. March 2002. "Commercial Buildings Determinations, Explanation of the Analysis and Spreadsheet (90_1savingsanalysis.xls)." http://www.energycodes.gov/implement/determinations_com.stm

A.8 Lighting R&D

Emerging Technologies Decision Unit

Project Objective:[1]

The Lighting R&D project develops and accelerates the introduction of advanced lighting technologies.

Long-Term Goal:[1]

The project's long-term goal is to reduce lighting energy use by 50% by 2020.

Market Segment

Target Market

- **Market Description:** The market includes all commercial buildings, with some technologies being introduced into residential buildings.
- **Size of Market:** Lighting consumes 26% (3.9 quad) of the primary energy used in commercial buildings, which had a building stock of ~69 billion sq ft in 2000[2].

Methodology

The energy savings from the lighting project are generally based on the judgment of the BT project managers and PNNL analysts as to the probable penetration of specific lighting technologies. Beginning with the FY 2003 GPRA process, an effort was made to estimate energy savings from BT activities designed to increase the adoption and effectiveness of lighting controls. PNNL continues to use a spreadsheet to develop the energy savings estimates for this project.

Various field studies[3] have shown a very large energy savings potential for lighting controls, primarily using occupancy and daylighting controls. These studies have shown that aggressively implementing controls can save 20% to 40% of lighting energy use. BT supports the development of more advanced systems—through both research and field testing—that will further reduce energy used for lighting in commercial buildings. BT support of research to evaluate the interrelationship between human vision and efficient light use will also contribute to future energy savings.

Lighting R&D

Project Type:
Equipment efficiency

Target Market:
Potentially all sectors and all climate zones (primarily impacts commercial sectors and higher-income residential)

End Uses:
Lighting and electricity

Unit of Measurement:
Lumens/watt

Modeling Tool:
Spreadsheet

Project Manager:
Ron Lewis

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
1.3	2.5	14.7	39.7

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.024	0.047	0.301	0.773

Consumer Cost Savings (million $):

2004	2005	2010	2020
9	16	98	312

For FY 2004, the impact of the BT activities in lighting controls and efficient lighting practices was assumed to yield an incremental 5% reduction in lighting energy use compared with current practice. (By *incremental*, the BT activities are assumed to lead to further savings

A.8 Lighting R&D

Emerging Technologies Decision Unit

over and above the control technologies that the private sector offers now and are likely to offer.)

This assumption represents a technical potential—PNNL further assumed that up to 80% of new commercial buildings could incorporate these technologies and that 20% of the existing stock could be retrofitted with these systems. A time profile of penetration rates was based on the historical pattern of market penetration observed for electronic ballasts. An S-shaped penetration curve was fit to historical market shares for electronic ballasts and then applied to project future adoption of advanced lighting distribution systems and controls. (This curve indicated that ~50% of the ultimate market penetration was achieved after 9 years).

PNNL developed a simple spreadsheet model to generate the energy savings estimates based on these assumptions. NEMS-PNNL was not used because it primarily competes different types of lighting sources—the BT activities in this area are designed to reduce the demand for all lighting sources. Implicitly, NEMS-PNNL requires input assumptions regarding lighting demand (lumen/sq ft), but these values are fixed over the forecast horizon. BESET also cannot modify lighting demands over time.

The spreadsheet model required several key baseline inputs. Projected annual floor space additions by building type were based on *Annual Energy Outlook 2001*[4] and were taken from the BESET database. PNNL took the baseline energy use per square foot for lighting by building type from PNNL's 1997 study to estimate end-use energy consumption for U.S. commercial buildings.[5] We applied the model to the following building types: offices, retail, education, health services, assembly, and lodging.

The spreadsheet approach embodies a somewhat different methodology compared with BESET to determine the savings in existing buildings. Existing buildings in the spreadsheet model are all buildings that did *not* adopt the BT-sponsored technologies during construction and thus include the current (2003) stock of buildings as well as those that will be built during the forecast period but that do not initially install these technologies.

In BESET, existing buildings primarily refer only to buildings built before the base year of the forecast horizon (e.g., pre-2004 buildings). The approach in this analysis reflects the assumption that future renovations of both existing and post-2003 buildings will provide opportunities to economically install these technologies.

These assumptions lead to an estimate of ~18.5 billion square feet of commercial buildings adopting these technologies by 2020, with a little more than half of the adoptions occurring after the buildings were first constructed (i.e., existing buildings). This amount of floor space represents ~31% of the total floor space in the building types considered.

Project/Technology Consumer Costs (PNNL Estimates):

- Incremental investment costs were developed assuming a 4-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $4).

A.8 Lighting R&D

Emerging Technologies Decision Unit

Non-Energy Benefits:

- Develops U.S. leadership in lighting technology
- Reduces pollution and contributes to U.S. climate change goals
- Improves U.S. productivity from better lighting in work environments
- Responds to an industry-initiated collaborative.

Sources:

(1) FY 2002 Budget Request – *Data Bucket Report for Lighting R&D Program* (internal BTS document).
(2) *Annual Energy Outlook 2002*. 2002. Energy Information Administration, Washington, D.C.
(3) See http://eande.lbl.gov/btp/450gg/publications.html and www.cmpco.com/services/pubs/lightingfacts/controls.html
(4) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.
(5) Belzer, D.B., and L.E. Wrench. 1997. *End-Use Energy Consumption Estimates for U.S. Commercial Buildings, 1992*. PNNL-11514, Pacific Northwest National Laboratory, Richland, Washington.

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

Project Objective:[1]

The Next Generation Lighting Initiative develops and accelerates the introduction of solid-state lighting and seeks to achieve the following for lighting:

- Significantly greater efficacy than conventional sources, such as T8 fluorescents
- Easy integration into building systems of the future
- Ability to provide the appropriate color and intensity for any application
- Ability to last 20,000 to 100,000 hours
- Ability to readily supplement natural sunlight.

Long-Term Goal:[1]

The project's long-term goal is to reduce lighting energy use by 50% by 2020.

Market Segment

Target Market

- **Market Description:** The market includes all commercial buildings, with some technologies being introduced into residential buildings.
- **Size of Market[4]:** Lighting consumes 26% (3.9 QBtu) of the primary energy used in commercial buildings, which had building stock of ~69 billion ft^2 in 2000.[b]

Methodology

The energy savings from the lighting project are generally based on the judgment of the BT project managers and PNNL analysts as to the probable penetration of specific lighting technologies. Formally, however, NEMS-PNNL was used to develop the savings calculations. The capital costs of the technologies are adjusted to achieve approximate congruence with the external penetration assumptions. The FY 2004 GPRA process focuses on solid-state lighting, which is expected to have a substantial increase in funding.

Lighting R&D: Next Generation Lighting

Project Type:
Equipment efficiency

Target Market:
Potentially all sectors and all climate zones (primarily impacts commercial sectors and higher-income residential)

End Uses:
Lighting and electricity

Unit of Measurement:
Lumens/watt

Modeling Tool:
NEMS-PNNL

Project Manager:
Ron Lewis

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.0	0.0	0.0	44.6

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.00	0.00	0.00	0.867

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	0	0	350

[b] According to a recent report completed for DOE by Navigant Consulting ("U.S. Lighting Market Characterization, Volume I: National Lighting Inventory and Energy Consumption Estimate," September 2002), the amount of energy used for lighting is greater than EIA has traditionally estimated. The report estimates that commercial lighting requires 4.2 QBtu and residential lighting requires 2.2 QBtu. This report, however, was distributed after the FY04 GPRA estimates were prepared, so PNNL's estimates are based on EIA's estimates.

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

Key assumptions concerning the likely dates of introduction and the expected efficacies were influenced by two sources: 1) "The Case for a National Research Program on Semiconductor Lighting,"[2] a white paper prepared by Hewlett-Packard and Sandia National Laboratories and presented in late 1999 at an industry forum; and 2) a more extended study[3] by A.D. Little for BT in early 2001; the study used some of the basic assumptions in the white paper[2] in developing some scenarios related to solid-state lighting.

The most recent work pertaining to the goals of the Next Generation Lighting Initiative, however, is a series of cost and performance projections prepared by Lincoln Technical Services (LTS) in the fall of 2002.[c] For the FY04 GPRA effort, the LTS estimates were used exclusively to drive the input assumptions used in the NEMS-PNNL model.

The LTS estimates were predicated on a substantial rampup of funding for this area of research by DOE. Within about five years, the funding for this activity was expected to increase to about $50 million per year, remaining at that level for a decade or longer. A set of energy savings estimates was developed in October of 2002 that reflected this scenario.

In late January of 2003, PNNL was asked to prepare a revised set of estimates based on a substantial scaling back of the proposed increase in this research area, corresponding to the final BT budget request. The revised budget case calls for some increase in funding, and then leveling out at about $5 million per year. The DOE program manager, Jim Brodrick, suggested that this reduction would likely stretch out the project goals for a viable commercial product by seven years or longer. Moreover, the rate of improvement and cost reduction, envisioned in the LTS projections, would also be reduced. These assumptions were used to modify the LTS projections as inputs to the NEMS-PNNL model.

As with the previous work for the FY 2002 and FY 2003 GPRA process, we used the NEMS-PNNL model to project energy savings from the initiative. The current model competes a wide variety of technologies and incorporates the EIA's functions that were used to represent declining costs of new technologies.

For the FY 2004 GPRA estimate, the savings estimates are based on NEMS-PNNL projections modeling the solid-state lighting technologies supported under the Next Generation Lighting Initiative. In either budget scenario, this initiative will increase the research funding for the solid-state lighting sources. The approach suggested by the National Research Council is that the commercial introduction of these technologies might be advanced by ten years as a result of DOE's role. However, in the case described here, the energy savings path essentially assumes that the technology would not be introduced without DOE support. In part, this assumption stems from the time horizon of the *Annual Energy Outlook 2002* version of NEMS-PNNL that does not extend beyond 2020.

NEMS-PNNL characterizes each lighting technology by source efficacy level (lumens/watt), capital cost ($/1000 lumens or $/kLumen), and annual maintenance cost of lamps. For new

[c] Spreadsheet named Dave.data1.xls transmitted by Michael Scholand of Navigant Consulting, Inc. on October 30, 2002.

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

technologies, the capital costs can be reduced along a logistic-shaped curve. The NEMS-PNNL model divides the commercial lighting market into four major groups: 1) incandescent CFL (point source), 2) 4-foot fluorescent, 3) 8-foot fluorescent, and 4) high-intensity point source (outdoor lighting). Solid-state lighting was assumed to penetrate the first three market groupings.

Given the cost assumptions, the NEMS-PNNL model chooses among these technologies for each building type in each census division. For each group, the market is assumed to be further segmented, with each segment characterized by a different discount rate in its decision-making criteria. Within each segment, a lighting technology is selected based on minimum annualized cost.

Table A-9.1 summarizes the cost inputs for some of the key lighting technologies used in NEMS-PNNL for FY 2004. The first round of FY 2004 estimates (consistent with the substantially higher budget levels) was based upon the efficacy of solid-state lighting reaching 160 lumens/watt in 2010, 180 lumens/watt by 2015, and 208 lumens/ watt by 2018. In the revised budget case, as the table shows, the 160 lumen/watt performance goal was delayed until 2017. Some improvement in the performance and a decrease in cost was assumed for the 2019 input.

Non-Energy Benefits:

- Helps maintain U.S. semi-conductor leadership
- Develops U.S. leadership in lighting technology
- Reduces pollution and contributes to U.S. climate change goals
- Improves U.S. productivity from better lighting in work environments
- Responds to industry-initiated collaborative.

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

Table A-9.1. Solid-State Lighting Cost and Efficiency Assumptions—FY 2004 GPRA

	Efficacy (Lumen/ watt)	Light Source Cost ($/kLumen) (2010)	Light Source Cost ($/kLumen) (2017)	Light Source Cost ($/kLumen) (2019)	Light Source Cost ($/kLumen) (2020)	Annual Oper. Cost ($/yr)
Incandescent / CFL						
Incandescent A19	15	0.25	0.25	0.25	0.25	6.50
CFL (pin-base, 20 watts)	60	4.89	4.70	4.52	4.34	1.75
CFL (integral, 20 watts)	60	8.00	7.69	7.39	7.10	1.75
Solid state (2017 intro)	160	NA	12.00	12.00	12.00	0.87
Solid state (2019 intro)	164	NA	NA	11.20	11.20	0.87
4-foot Fluorescent						
Halogen reflector lamp	14	5.84	5.84	5.84	5.84	15.77
F32T8 Electronic	80	1.01	0.97	0.93	0.90	2.80
Solid state (2017 intro)	160	NA	12.00	12.00	12.00	2.53
Solid state (2019 intro)	164	NA	NA	11.20	11.20	0.87
8-foot Fluorescent						
F96T12 - Electronic ES	61	3.01	2.89	2.77	2.66	5.25
F96T12 - Electronic HO	52	1.88	1.81	1.74	1.67	9.64
Solid state (2017 intro)	160	NA	12.00	12.00	12.00	2.50
Solid state (2019 intro)	164	NA	NA	11.20	11.20	0.87
NA = Not applicable.						

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

Sources:

(1) FY 2002 Budget Request – *Data Bucket Report for Lighting R&D Program* (internal BT document).
(2) Haitz, R., and F. Kish (Hewlitt-Packard Co) and J. Tsao and J. Nelson (Sandia National Laboratories). 1997. "Case for a National Research Program on Semiconductor Lighting," White paper presented at the 1999 Optoelectronics Industry Development Association forum in Washington D.C., October 6, 1999.
(3) A.D. Little. 2001. *Energy Savings Potential of Solid State Lighting in General Lighting Applications*. Prepared for DOE's Office of Building Technology, State and Community Programs by A.D. Little, Cambridge, Massachusetts.
(4) *Annual Energy Outlook 2002*. 2002. Energy Information Administration, Washington, D.C.

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Project Objective:[1]

This project develops and promotes the use of commercial food display and storage technologies that use less energy and less refrigerant. Water-heating activities are centered on developing low-cost, high-reliability heat pump water heater concepts. The project's HVAC delivery (e.g., duct work) technologies are intended to reduce the energy losses incurred in transferring heating or cooling from the conditioning unit(s) (e.g., heat pump, furnace, and air conditioner) to the conditioned space. The refrigerant pressure charge meter and coefficient of performance (COP) meter enables early warning of poor operation of HVAC equipment to keep installed equipment operating at design efficiencies during the service life.

Long-Term Goal:[1]

The long-term goal of this project includes reducing energy use for building space heating and cooling by 20% to 25% (22.5% assumed) and supermarket refrigeration and energy use by 10% to 20% (15% assumed) while reducing the level of refrigerant needed.

Market Segment:

Target Market

- **Market Description:**[1] The market includes commercial refrigeration, a broad classification of building equipment that collectively consumes about one quad of U.S. energy annually[2]. Supermarkets consume about one-third of the energy used in commercial refrigeration. Residential applications include air conditioners, heat pumps, heat pump water heaters, and thermal distribution systems associated with forced air systems.
- **Size of Market:** [1] Commercial refrigeration markets include ~30,000 large supermarkets and 100,000 convenience stores. Other markets include hospitals, large institutional buildings, and restaurants. Residential markets include new, single-family, and existing homes.

Methodology

For FY 2004, four technologies were modeled: commercial refrigeration, residential HVAC distribution

Space Conditioning and Refrigeration R&D

Project Type: Equipment efficiency

Target Market: Refrigeration: commercial food sales in all climate zones; Heat Pump Water Heater and HVAC Distribution: residential; Refrigerant Pressure Charge Meter and COP Meter: residential and commercial

End Uses: Heating, cooling, and water heating

Unit of Measurement: Refrigeration: % end-use consumption; Heat Pump Water Heater and Refrigerant Meter: efficiency/unit; HVAC Distribution: % change in load

Modeling Tool: Refrigeration: spreadsheet; HVAC Distribution, Heat Pump, Water Heater, and Refrigerant Meter: BESET

Project Manager: Arun Vohra

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FY 2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
2.0	5.2	58.7	335.4

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.032	0.088	1.074	6.178

Consumer Cost Savings (million $):

2004	2005	2010	2020
13	36	430	2882

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

systems (existing and new construction), advanced electric heat pump water heaters, and refrigerant pressure charge meters and COP meters.

Commercial Refrigeration

This project was modeled as an advanced supermarket refrigeration system that would target heating, cooling, and refrigeration end-use loads in the commercial food sales sector. These end uses comprise ~66% of total building, ~67% of electric, and 61% of total natural gas end-use energy consumption.[3]

To calculate the project's energy savings, the overall reduction in end-use energy consumption was applied to the estimated consumption per square foot within food sales buildings. This per-square-foot energy-savings level was aggregated to a project total based on a forecast of square feet of food sales buildings and an estimated market penetration curve.

Performance Objective:

- **Displaced Technology:** Conventional refrigeration equipment in food sales buildings.
- **Performance Target:** Reduced energy for building HVAC and refrigeration equipment over the next 15 to 20 years, specifically at least 15% for supermarket refrigeration and HVAC while reducing refrigerant needed. For FY 2004, PNNL assumed an overall 22.5% reduction in HVAC end-use energy consumption.

Market Penetration:

- **Target Market:** All commercial food sales buildings.
- **Market Introduction:** 2004; this project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.
- **Market Penetration Goal for New Buildings:** 93% penetration of all commercial food sales buildings by 2020 and 99% by 2030 (see Figure A-10.1).

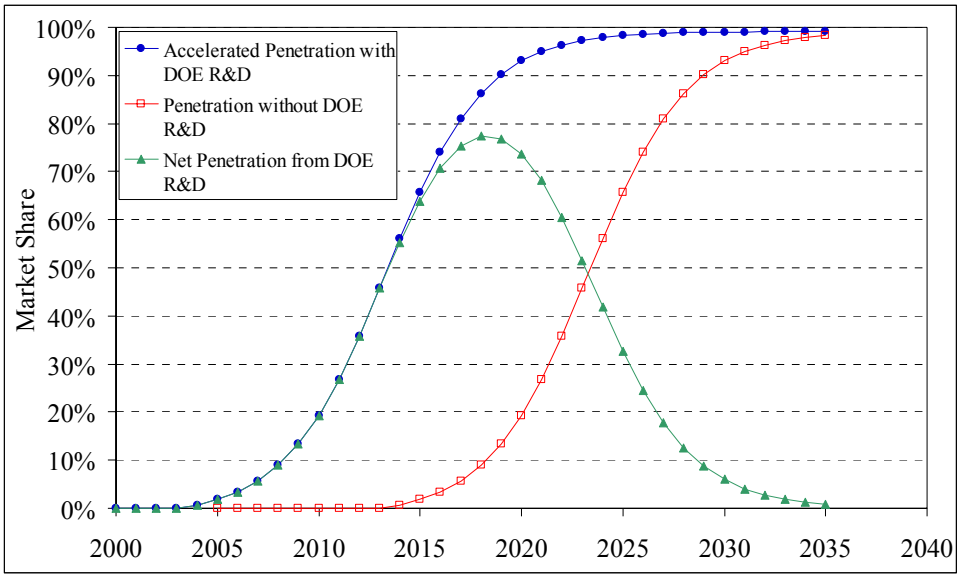

Figure A-10.1. Market Penetration Curve for Commercial Refrigeration

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 3-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $3).

Residential HVAC Distribution Systems – Existing Construction

This technology, aeroseal sealing, and other projects designed to reduce duct leakage in existing residences will reduce the energy liabilities of residential ductwork. PNNL determined this project's energy savings by using BESET and applying overall percentage reductions in heating, cooling, and ventilation to the estimated consumption per square foot within existing single-family buildings. Ventilation consumption and savings were assumed to be included in the heating and cooling consumption and savings. The per-square-foot energy-savings level was then aggregated to a project total based on a forecast of single-family building square feet and an estimated market penetration curve.

Performance Objective for Existing Construction:

- Displaced Technology: Current duct work, with the performance described in Table A-10.1.
- Performance Target: Table A-10.1 shows the reductions in HVAC end-use energy consumption that were assumed for FY 2004.

Table A-10.1. Assumed Reductions in Energy Use for Residential HVAC Distribution Systems (existing construction)

End Use	Percentage Reduction in Energy Consumption
Heating	13.8*
Cooling	6.9**

* Conductive and air leakage losses have about equal contribution to duct system energy loss.[4] The energy savings associated with duct sealing is assumed to be roughly equivalent to the savings possible through better design. The seasonal heating distribution (which includes conduction through duct walls and air leakage through duct system holes and joints for ducts located in unconditioned spaces) efficiency of typical current ducts is ~56% and ~72% for good conventionally designed ducts with R-4 duct insulation.[5] Single-family buildings with ducts can reduce heating energy consumption by 22.2% (1 – 56%/72%). With ~50% of existing single-family homes using ducts,[4] the overall per building heating savings are 11.1% (22.2% * 50%).

** The seasonal cooling efficiency of typical current ducts is ~75% and ~87% for good conventionally designed ducts with R-4 duct insulation.[5] Single-family buildings with ducts can reduce cooling energy consumption by 13.8% (1 – 75%/87%). With ~50% of existing single-family homes using ducts,[6] the overall per building cooling savings are 6.9% (13.8% * 50%).

Market Penetration for Existing Construction:

- Market Introduction: 2004; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 10 years
- Market Penetration Goal: 20% of existing single-family units by 2020 (see Figure A-10.2).

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

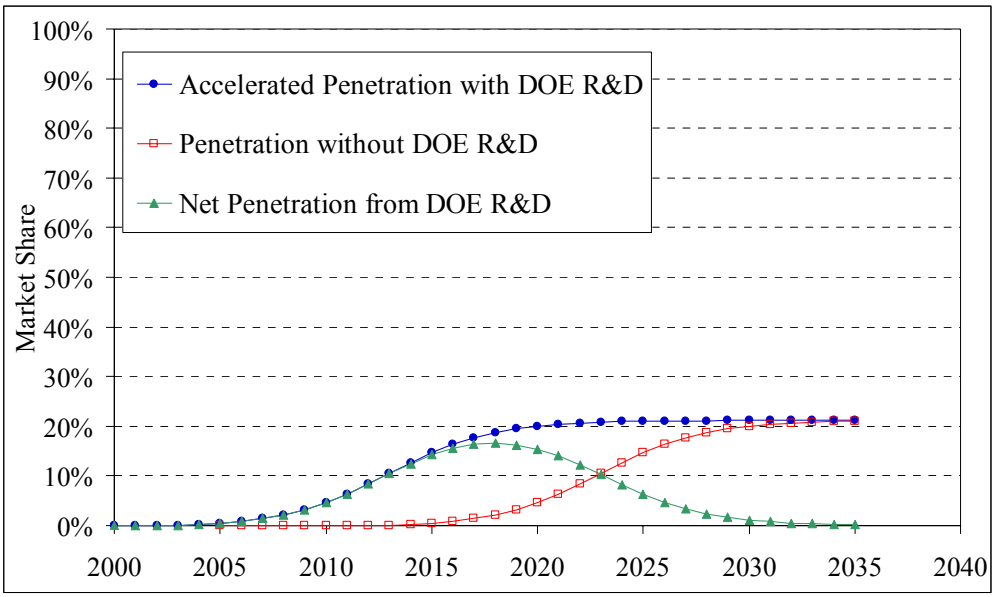

Figure A-10.2. Market Penetration Curve for Residential HVAC Distribution Systems (existing construction)

Project/Technology Consumer Costs (PNNL Estimate):

- Cost of Conventional Technology: $0.00
- Cost of BT Technology: $480
- Incremental Cost: $480/residence.

Residential HVAC Distribution Systems – New Construction

This technology, ducts in the conditioned space, and four other projects addressing the insulation issues associated with ducts,[d] will reduce the energy liabilities associated with residential ductwork. PNNL determined this project's energy savings by using BESET and applying overall percentage reductions in heating, cooling, and ventilation to the estimated consumption per square foot within new single-family buildings. We assumed that ventilation consumption and savings were included in the heating and cooling consumption and savings.

The per-square-foot energy-savings level were then aggregated to a project total based on a forecast of single-family building square feet and an estimated market penetration curve.

Performance Objective for New Construction:

- Displaced Technology: Current duct work, with the performance outlined in Table A-10.2.
- Performance Target: Table A-10.2 shows the reductions in HVAC end-use energy consumption that were assumed for FY 2004.

[d] E-mail from Esher Kweller, former project manager, to Dave Belzer, November 8, 2001.

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Table A-10.2. Reductions in HVAC Energy Use for Residential Distribution Systems (new construction)

End Use	Percentage Reduction in Energy Consumption
Heating	17.2*
Cooling	8.7**

* Conventional design with R-8 duct insulation has a seasonal heating efficiency of ~80% and ~72% (average 76%) with R-4 duct insulation, while ducts in the conditioned space have a seasonal heating efficiency of ~94%;[4] therefore, the percentage reduction in heating energy consumption in single-family buildings with ducts is 19.1% (1 – 76%/94%). Of new residential construction, ~90% use ducts.[3] Therefore, the overall per building heating savings are 17.2% (19.1% * 90%).
** Conventional design with R-8 duct insulation has a seasonal cooling efficiency of ~90% and ~87% with R-4 duct insulation (average 88.5%), while ducts in the conditioned space have a cooling seasonal efficiency of ~98%%.[4] Therefore, the percentage reduction in cooling energy consumption in single-family buildings with ducts is 9.7% (1 – 90%/98%). Of new residential construction, ~90% use ducts.[3] Therefore, the overall per building cooling savings are 8.7% (9.7% * 90%).

Market Penetration for New Construction:

- **Target Market:** New single-family units in all climate zones.
- **Market Introduction:** 2004; this innovation is assumed not to occur without the DOE project.
- **Market Penetration Goal:** 20% of new single-family units by 2020 (see Figure A-10.3).

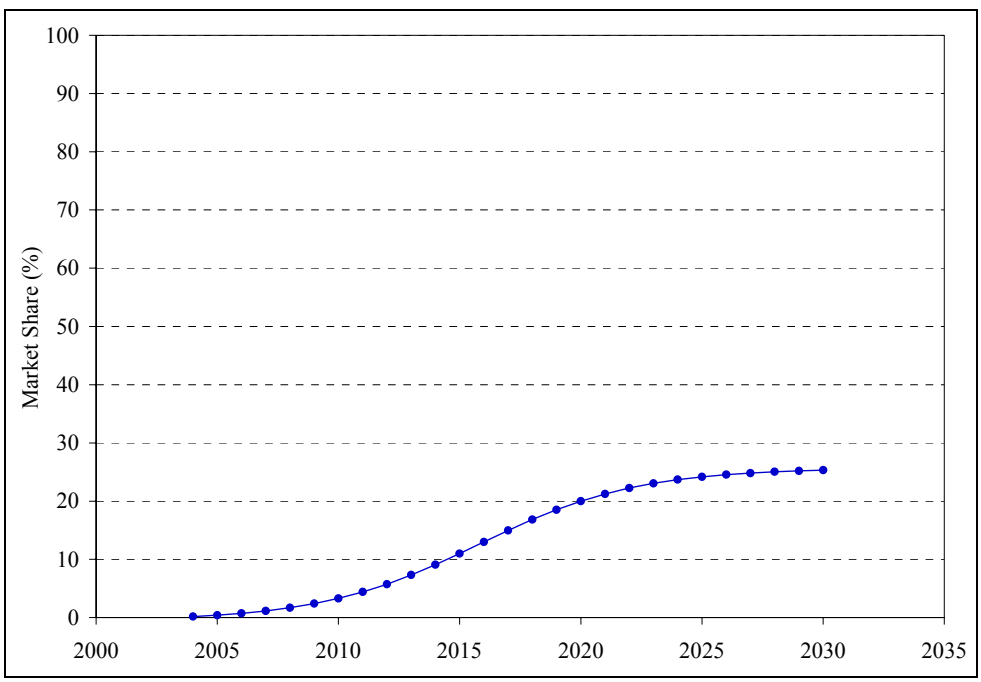

Figure A-10.3. Market Penetration Curve for Residential HVAC Distribution Systems (new construction)

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Project/Technology Consumer Costs (PNNL Estimate):

- **Cost of Conventional Technology:** $0.00
- **Cost of BT Technology:** $1000
- **Incremental Cost:** $1000/residence

Advanced Electric Heat Pump Water Heaters

This technology will increase the efficiency of residential and commercial electric water heating equipment and reduce peak energy use. The purpose of this program is to improve the cost effectiveness of heat pump water heaters mainly through lower capital costs. PNNL used BESET to determine this project's energy savings.

Performance Objective:

- **Displaced Technology:** Current electric water heater technology with an EF of .93.
- **Performance Target:** 1.8 energy factor.

Market Penetration:

- **Target Market:** Residential and commercial.
- **Market Introduction:** 2005; this project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.
- **Market Penetration Goal:** 6% by 2015 and 10% by 2020 (see Figure A-10.4).

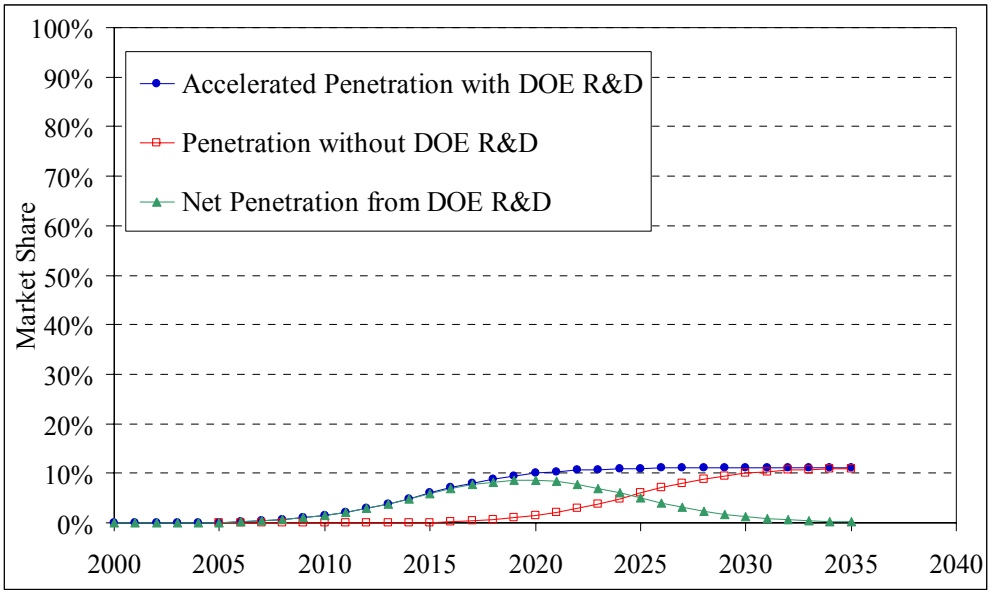

Figure A-10.4. Market Penetration Curve for Advanced Electric Heat Pump Water Heaters

Project/Technology Consumer Costs (PNNL Estimate):

- **Cost of Conventional Technology:** $350
- **Cost of BT Technology:** $1025
- **Incremental Cost:** $675/unit.

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Refrigerant Pressure Charge Meters and COP Meters

This technology will increase the efficiency of residential and commercial space conditioning equipment and reduce peak energy use. Most air conditioning units and heat pumps have an improper refrigerant charge level or other issue resulting in a COP that is lower that design. These meters will inform the homeowner or business owner of the current state of charge or performance of their space conditioning equipment and ultimately the increased cost. Given this information, that is currently not readily available, it is expected that prudent owners will get the situation corrected. PNNL determined this project's energy savings by using BESET and applying overall percentage reductions in vapor compression heating and cooling energy consumption.

Performance Objective:

- **Displaced Technology:** None, because this technology an addition to both existing and future technologies. It provides a service not previously available.
- **Performance Target:** Table A10.3 shows the assumed reductions in HVAC end-use energy consumption for FY 2004.

Table A-10.3. Assumed Reductions in Energy Use for Refrigerant Pressure Charge Meters and COP Meters

End Use	Percentage Reduction in Energy Consumption
Residential Heat Pump Heating	23.9*
All Residential Cooling (includes heat pumps)	23.9
Commercial Heat Pump Heating	12.0**
Commercial Vapor Compression Cooling (includes heat pumps and excludes chillers)	12.0

* This value is based on a frequency distribution of undercharging and overcharging and on an efficiency impact associated with each level of undercharging and overcharging. http://www.proctoreng.com/checkme/technical.html.

** While the impact of undercharging and overcharging in commercial equipment is roughly the same as residential equipment, the frequency of undercharging and overcharging is believed to be about half that in residential equipment.

Market Penetration (PNNL estimates):

- **Market Introduction:** 2005; PNNL assumed this project accelerated the introduction of this technology into the marketplace by 10 years.
- **Market Penetration Goals:** 50% of all applicable residential units by 2020 and 90% of all applicable commercial units by 2020 (see Figures A-10.5 and A-10.6).

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

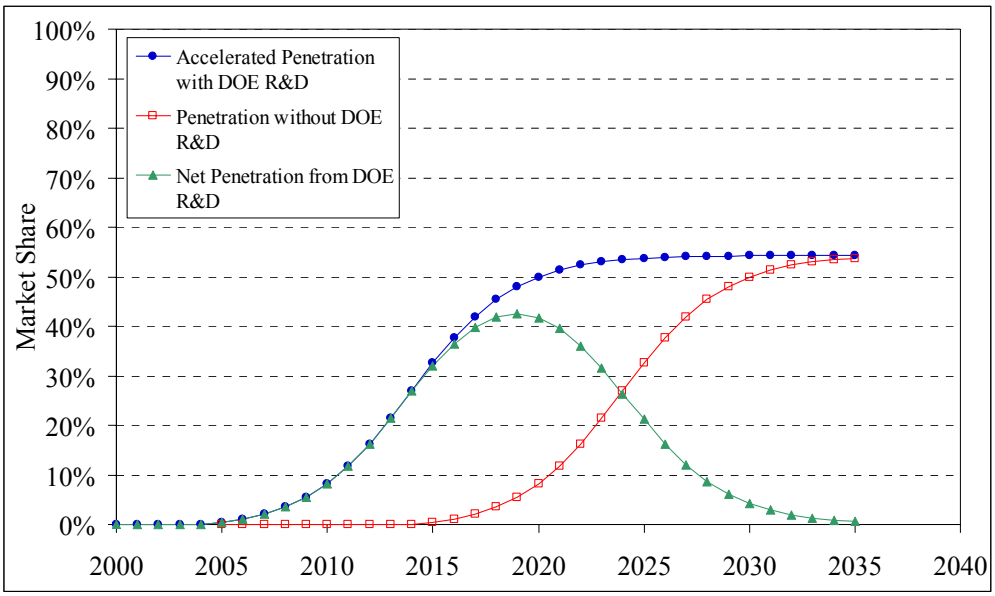

Figure A-10.5. Residential Market Penetration Curves for COP and Refrigerant Pressure Change Meters

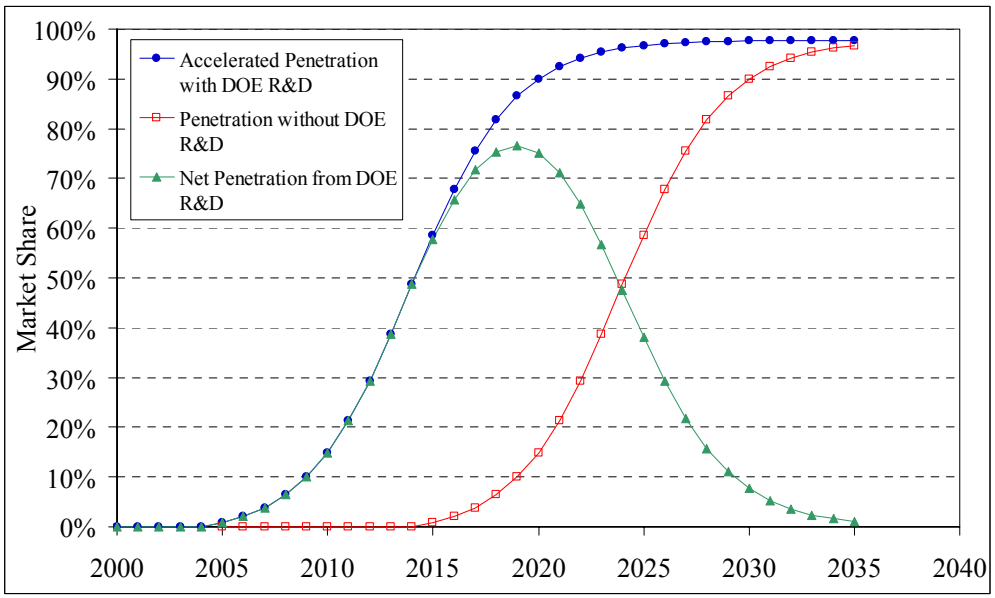

Figure A-10.6. Commercial Market Penetration Curves for Refrigerant and COP Meters

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Project/Technology Consumer Costs (PNNL estimates):

- **Cost of Conventional Technology:** $0.00.
- **Cost of BT Technology:** $100.00.
- **Incremental Cost:** $100.00.

Non-Energy Benefits:

- Reduced carbon emissions
- Economic benefits to the private sector
- Reduced pollution from leaking refrigerant
- Improved indoor air quality from better humidity control.

Sources:

(1) FY 2002 Budget Request - *Data Bucket Report for Space Conditioning and Refrigeration: Refrigeration Program* (internal BTS document).
(2) Arthur D. Little, Inc. 1996 *Energy Savings Potential for Commercial Refrigeration Equipment.* Reference 46230-00. Cambridge, Massachusetts.
(3) Belzer, D.B and L.E. Wrench. 1997. *End-Use Consumption Estimates for U.S. Commercial Buildings, 1992*. PNNL-11514, Pacific Northwest National Laboratory, Richland, Washington.
(4) Brookhaven National Laboratory. 2001. *Better Duct Systems for Home Heating and Cooling*. BNL-68167, Vol. 1, Upton, New York.
(5) Brookhaven National Laboratory. 2001. *Better Duct Systems for Home Heating and Cooling*. BNL-68167, Vol. 4, Upton, New York, p.10.
(6) Brookhaven National Laboratory. 2001. *Better Duct Systems for Home Heating and Cooling*. BNL-68167, Vol. 3, Upton, New York, p.1.

A.11 Appliances and Emerging Technologies R&D

Emerging Technologies Decision Unit

Project Objective:[1]

This project helps manufacturers and utilities commercialize highly efficient appliances and equipment by providing the following assistance:

- Technology procurement to bring new technologies to market (late developmental work), which can bridge the gap between traditional R&D and mainstream deployment.
- To increase market share of emerging technologies and Energy Star technologies with very low market penetration, via independent third-party evaluation and verification of highly efficient technologies using field studies and demonstrations.
- R&D on appliances not covered by other projects but offering significant energy-savings potential.

Long-Term Goals :[1]

The project's long-term goal is to transform key energy product markets by working with industry partners to commercialize highly efficient technologies. Once established in the mainstream market, the technologies can become the basis for other approaches, such as Energy Star labeling or minimum efficiency standards.

Market Segment:

Target Market

- **Market Description:** The market includes residential and commercial building technologies, with emphasis on appliances and water heating.
- **Size of Market:** The market size depends on the various equipment:
  - **Heat Pump Water Heaters:** 13.6 million existing homes of the potential 44 million homes with electric resistance water heaters and ~40% of new homes. Limited, but initial market, for light commercial.
  - **Gas-Condensing Water Heaters:** ~20 million existing homes of the potential 60 million homes and ~40% of new homes.
  - **Rooftop Air Conditioners:** One of the most widely used technologies with greatest commercial space conditioning energy use; over a million tons sold in 1998.
  - **Residential Can Lights:** An estimated 22 million incandescent can fixtures sold in 2001.

Appliances and Emerging Technologies R&D

Project Type: Equipment efficiency

Target Market: All sectors, all climate zones

End Uses: Water heaters, lighting, and space cooling

Unit of Measurement: Efficiency of specific equipment type

Modeling Tool: NEMS-PNNL (heat pump water heater, rooftop air conditioner, gas-condensing water heater) and BESET (recessed can lights and R-lamps)

Project Manager: Jim Brodrick

Website: www.eren.doe.gov/buildings/emergingtech/index.html

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FY2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
4.7	11.2	77.1	127.7

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.084	0.207	1.537	2.357

Consumer Cost Savings (million $):

2004	2005	2010	2020
33	78	623	1143

– **Reflector CFLs (R-lamps):** ~125 million parabolic/reflector lamps sold to the residential market.

Methodology

PNNL modeled the lighting projects, recessed cans and R-lamps, with BESET and others using NEMS-PNNL. Key inputs and output for emerging technology's heat pump water heaters, roof top air-conditioners, and gas-condensing water heaters are described in the following sections.

NEMS Modeling of Emerging Technologies

PNNL modified the NEMS-PNNL residential model to represent heat pump water heaters and condensing gas water heaters and used the NEMS-PNNL commercial model for high-efficiency rooftop air conditioners. We modified several NEMS input files (RTEKTY.txt for residential, KTECH.wk1 for commercial) to produce the NEMS-PNNL results for each characterized technology. The baseline assumptions made by EIA, the cost and performance attributes of the BT-sponsored technologies, and the resulting market shares for these most energy-efficient technologies are documented in the following sections. For a few appliances, some changes were made in EIA's baseline assumptions; the reasons for these changes are briefly discussed.

General Methodology

For FY 2004, the water heater technologies funded by the Emerging Technologies project were modeled only in the residential model. The residential model uses a logit specification to estimate the market shares of specific technologies for a given type of appliance. For each appliance, two parameters generally influence how consumers value the tradeoff between the initial purchase cost versus the annual operating cost of the appliance. The annual operating cost depends on the energy efficiency of each technology (or "model") and the price of energy.

Heat Pump Water Heater

The purpose of this project is to expand the market for heat pump water heaters. Field testing, data collection, workshops, and potentially volume purchasing are elements of this project.

- **Market Introduction:** 2003; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 10 years.
- **Performance Target:** 2.47 energy factor.
- **Penetration Target:** 10% by 2015.
- **Installed Cost:** Initial installation cost of $700, decreasing to $650 in 2006.
- **Lifetime:** 10 years.

The input file used for *Annual Energy Outlook 2001*[2] includes several categories of heat pump water heaters, two having installed costs of >$1,000. With the discount rates used in *Annual Energy Outlook 2001* for electric water heaters, only a very small number of the $1,025 units are predicted to be sold (no higher-costs unit). A more moderately priced heat pump unit is assumed to become available in 2005, with a cost of $900 and an energy factor of 2.0. By 2015, the cost of this unit is assumed to fall to $800 and the energy factor to increase to 2.2.

A.11 Appliances and Emerging Technologies R&D

Emerging Technologies Decision Unit

The original *Annual Energy Outlook 2001* input file does not reflect the pending water heater standards that are scheduled to take effect in 2004. Two modifications were made to account for these standards (shown at the top of Table A-11.1):

1. Technology #1 (see Table A-11.1) was assumed to be unavailable after 2003 and therefore was dropped from the list of technologies available to consumers in the GPRA FY 2004 time horizon.

2. The efficiency for technology #2 was changed to 0.89 with an unchanged cost (see revised characteristics under technology labeled #2a in Table A-11.1).

Table A-11.1. Key NEMS-PNNL Inputs for Electric Water Heaters

Technology	Start Year	End Year	Energy Factor	Installed Cost	Type
1	1997	2003	0.86	$350	Resistance
2	1997	2003	0.88	$350	Resistance
2a	2003	2020	0.89	$350	Resistance
3	1997	2020	0.95	$575	Resistance
4	1997	2020	2.60	$1,025	Heat Pump*
5	1997	2020	2.00	$2,600	Heat Pump
6	1997	2020	0.90	$360	Resistance
7	2005	2020	0.96	$475	Resistance
8	2004	2009	2.47	$700	Heat Pump**
9	2015	2020	0.90	$400	Resistance
10	2015	2020	0.96	$425	Resistance
11	2006	2020	2.47	$650	Heat Pump**

* Inexplicably, the lower-cost unit is assumed to have a higher efficiency.
** Appliances and Emerging Technologies project.

The Appliances and Emerging Technologies project is assumed to lead to a more rapid commercialization of a moderately priced heat pump water heater, first available in 2003. However, the project's principal impact is to achieve a lower cost than the unit assumed to be introduced in 2005 in the *Annual Energy Outlook 2001* base case. As Table A-11.1 shows, the heat pump water heater units supported by emerging technologies are assumed initially to have energy efficiency rating of 2.47 and an installed cost of $700.[e] By 2006, further development will yield a unit with the same energy factor (2.47) at lower cost ($650).

One issue related to assessing benefits of this technology with the NEMS-PNNL model is the appropriate discount rate to use. The logit parameters in the NEMS-PNNL model related to the choice of electric water heaters are -0.0162 (Beta1) and -0.0195 (Beta2), implying a discount

[e] The influence of emerging technologies research is assumed to reduce the unit from $900 (Annual Energy Outlook 2001base case) to $700.

rate of ~83%.[f] At this discount rate, the high initial cost of the heat pump water heater, even with its much higher efficiency, discourages most consumers from choosing this technology. A more robust assessment of the project is obtained by assuming that the ongoing Energy Star project for water heaters provides impetus for increased market acceptance of the heat pump water heater.[g] In this scenario, the changes in the discount rates assumed for Energy Star project are combined with the introduction of the (lower-cost) heat pump water heater.

The *Annual Energy Outlook 2001* baseline parameters that determined the market share for electric water heaters are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0162}{-0.0195} \approx discount\ rate = 83\%$$

With the support of the Appliances and Emerging Technologies and the Energy Star projects, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0072}{-0.0195} \approx discount\ rate^{E-Star} = 37\%$$

As Table A.11.2 shows, the lower discount rates generate much higher penetrations of the heat pump water heater, ultimately reaching nearly 25% of sales by 2010. While Table A-11.2 displays the shares for only new homes, the shares for the replacement market are similar.

The project's energy savings were calculated as the difference between NEMS-PNNL model runs that do the following:

1. Include the heat pump waters assumed in the AEO base case.
2. Substitute the lower-cost units assumed to stem from the Emerging Technologies project.
3. Assume Energy Star influence on deploying technology such that discount rate is reduced for water heaters.[h]

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[f] Within NEMS-PNNL, the two modeling parameters determining the discount rate are labeled Beta1 and Beta2. Beta1 is used as a multiplicative factor with the initial cost of the appliance. Beta2 is used to multiply the annual energy cost. As a rough approximation, the ratio of Beta1/Beta2 can be interpreted as the consumer discount rate for the specific appliance.

[g] Market transformation projects, such as Energy Star, attempt to accelerate market penetration of existing high-efficiency technologies. From a modeling standpoint, these efforts translate into reducing the consumer's discount rate for these energy-efficient products. See the documentation specific to Energy Star project for more information.

[h] In both runs, the adjustments to the discount rate (via the Beta1 coefficient) were the same as those used in evaluating the Energy Star project for water heaters. The assumption of an ongoing Energy Star project raises the question of whether the Energy Star project should receive some of the credit for energy savings from this technology. No clear methodology exists for decomposing the benefits between applied R&D project and market conditioning activities. If such an attribution must be made for the

Table A-11.2. NEMS-PNNL Results for Heat Pump Water Heaters (national market shares[i] for new single-family homes)

Year	Market Share with *Annual Energy Outlook 2001* Discount Rate	Market Share with Adjusted NEMS-PNNL Discount Rates
2004	0.024	0.040
2005	0.012	0.031
2006	0.012	0.050
2007	0.012	0.077
2008	0.012	0.116
2010	0.028	0.239
2015	0.047	0.241
2020	0.048	0.243

In essence, the heat pump water heaters' savings were calculated as the difference between an Energy Star project with and without the units developed under the Appliances and Emerging Technologies project. (The Energy Star project characterization, in Appendix B, contains further discussion of the savings from the Energy Star project without these lower-cost heat pumps.)

Gas-Condensing Water Heater

- **Market Introduction:** 2002; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 10 years.
- **Performance Target:** Energy factor of 0.80.
- **Penetration Target:** 9% to 10% by 2020.
- **Installed Cost:** Incremental cost of $150 to $200 over conventional technology. Estimated from a study that gives a price of $700.[4]
- **Lifetime:** 10 years.

The original *Annual Energy Outlook 2001*[2] input file does not reflect the pending water heater standards that are scheduled to take effect in 2004. To account for these standards in the gas water heater market, the technologies with energy factors <0.60 (0.54 and 0.58) were specified to be unavailable after 2003. These NEMS-PNNL modifications are shown in the top two lines of Table A.11.3. The EIA includes a high-efficiency condensing gas water heater in its menu of technology choices for the *Annual Energy Outlook 2001*. As Table A-11.3 shows, these units have very high costs. Not surprisingly, the model yields negligible market shares for this technology.

The Appliances and Emerging Technologies project is assumed to lead to the commercialization of a moderately priced condensing gas water heater, first available in 2005. As Table A-11.3 shows, the units are assumed initially to have an energy efficiency rating of 0.8 and cost $550

GPRA process, 70% of the savings are proposed to be assigned to the Appliances and Emerging Technologies project and 30% to Energy Star.

[i] The market shares in this discussion pertain only to electric water heaters.

Table A-11.3. Key NEMS-PNNL Inputs for Gas Water Heaters

Equipment Type	First Year Available	Last Year Available	Efficiency	Installed Cost	Type of Technology
3	1997	2004	0.6	$400	Noncondensing
3	2005	2020	0.6	$375	Noncondensing
4	1997	2004	0.86	$2,360	Condensing
4	2005	2014	0.86	$2,000	Condensing
4	2015	2020	0.86	$1,800	Condensing
5	2005	2014	0.63	$450	Noncondensing
5	2015	2020	0.63	$425	Noncondensing
6	2015	2020	0.7	$500	Noncondensing
26	2005	2020	0.8	$500	*Condensing
27	2010	2020	0.8	$475	*Condensing
*Emerging Technologies Project unit.					

(installed). By 2010, further development is assumed to yield a unit with a slightly lower cost ($525).

As with the heat pump water heater, an issue related to assessing benefits with the NEMS-PNNL model is the appropriate discount rate to employ. The logit parameters in the NEMS-PNNL model related to the choice of gas water heaters are -0.05393 (Beta1) and -0.1136 (Beta2), implying a discount rate of ~47%. At this discount rate, the higher initial cost of the BT-sponsored condensing gas water heater, even with its much higher efficiency, discourages most consumers from choosing this technology. The NEMS-PNNL results shown in column 2 of Table A.11.4 show that the market share only reaches ~1%, even with the lower-cost second-generation unit assumed in the analysis.

As with the heat pump water heater, a more robust assessment of the project is obtained by assuming that the ongoing Energy Star project for water heaters provides impetus for increased market acceptance of the condensing gas water heater. In this scenario, the changes in the discount rates assumed for Energy Star project are combined with the introduction of the (lower-cost) condensing gas water heater.

The *Annual Energy Outlook* baseline parameters that determined the market share for gas water heaters are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0539}{-0.1136} \approx discount\ rate = 47\%$$

With the support of the Appliances and Emerging Technologies and the Energy Star projects, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0359}{-0.1136} \approx discount\ rate^{E-Star} = 32\%$$

As Table A.11.4 shows, the lower discount rates generate much higher penetrations of the condensing water heater, ultimately reaching nearly 10% of sales by 2010. The inputs in *Annual Energy Outlook 2001* assume the introduction of a high efficiency noncondensing unit in 2015. This assumption is the principal explanation for why the share of the condensing unit drops between 2010 and 2020. While Table A-11.4 shows the shares for only new homes; the shares for the replacement market are similar.

Table A-11.4. NEMS-PNNL Results for Energy Star Gas Water Heaters (national market shares for new single-family homes)

Year	Market Share with *Annual Energy Outlook 2001* Discount Rate	Market Share with NEMS-PNNL Adjusted Discount Rate
2005	0.003	0.009
2006	0.003	0.015
2007	0.003	0.024
2008	0.003	0.038
2010	0.011	0.129
2015	0.009	0.100
2020	0.010	0.106

Rooftop Air Conditioning

- **Market Introduction:** 2004; the National Research Council (acceleration-to-market) methodology was not applied to this technology because the impact was determined to be negligible. Given that the technology has only modest penetration (10%) by 2020 and only a few percent by 2010, the National Research Council methodology would not have a significant impact over the analysis period.
- **Performance Target:** An efficiency increase from 10.3 to 11.0 energy efficiency ratio for 65 to 135 kBtu/hr and from 9.7 to 10.8 for 135 to 240 kBtu/hr.
- **Penetration Target:** 10% of sales in 2020.
- **Lifetime:** 15 years.

The rooftop air conditioner project uses competitive procurements of large numbers of units to stimulate the production of high-efficiency equipment. The immediate goal is to get high-efficiency equipment installed in buildings owned by the federal government and other state and local agencies. A long-term, key outcome of the project is to provide incentives for manufacturers to reduce the cost of this equipment to all potential and private sector buyers.

With this long-term goal in mind, PNNL adjusted the assumed costs of high efficiency roof top air conditioners in the NEMS-PNNL commercial model to reflect the principal influence of this

project. In NEMS-PNNL, two air conditioners were specified in the rooftop category—a baseline unit (energy efficiency ratio of 8.5) and a high-efficiency unit (energy efficiency ratio of 11.6). No subgroups were distinguished by capacity (e.g., 65 to 135 kBtu/hr vs. 135 to 240 kBtu/hr).[j]

For the GPRA analysis, the incremental cost was reduced by 40%, based on project goals. Given the proportion of the market assumed in the NEMS-PNNL to display high discount rates in the selection of equipment, this cost reduction yielded a 9% penetration of the high-efficiency unit in 2005. The penetration rate falls to 6% in 2010 possibly the result of a greater efficiency in the baseline units and/or lower energy costs.[k] By 2020, the proportion of the total stock using the high-efficiency unit is ~5%.

BESET Methodology

The size of the target market is determined by the building stock, existing equipment market shares, and the turnover or replacement rate of existing equipment. The BT technology is assumed to compete only with "new" units (or equipment sales). For new buildings, all units are considered new. For existing buildings, only units scheduled for replacement are considered eligible for the BT technology. The BT technology is assumed not to replace a piece of equipment unless the equipment was going to be replaced anyway. The penetration rates for new buildings refer to the penetration into buildings built in 2004 and beyond. The penetration into existing buildings is the penetration into all buildings built before 2004.

Residential Can Lights

- **Market Introduction:** 2003; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 10 years.
- **Performance Target:** Assumed efficacy of 51.3 lumens/watt. Actual project requirements should be similar to Energy Star, as Table A-11.5 shows. However, because incandescent lamps also have lower efficacies, the ratio between Energy Star compact fluorescent lamps and all incandescents was assumed to be the same regardless of type. See the Energy Star compact fluorescent lamp summary in Appendix B.

[j] PNNL developed an alternative technology spreadsheet to model the rooftop initiative in the Appliances and Emerging Technologies project. In the most recent version of NEMS-PNNL, the technology cost and performance inputs are in a spreadsheet, in which the user can adjust the *incremental* cost between baseline unit and the high-efficiency unit.

[k] The precise reasons for this behavior have not been thoroughly investigated.

Table A-11.5. Performance Targets for Residential Can Lights

Lamp Power (watts) and Configuration	Minimum Efficacy: Lumens/watt*
Reflector Lamp:	
Lamp power <20	33
Lamp power >=20	40
*Based on initial lumen date.	

- **Penetration Target:** 30% of recessed can lights by 2008. The 30% penetration rate was assumed to occur across all fixtures in a home; that is, a home was assumed to have either all CFL cans or all incandescent cans. In 2020, 7% of the incandescent market will be recessed can lights[3] (see Figure A-11.1); thus, this represents 2.1% of all incandescents.
- **Lifetime:** 30 years.

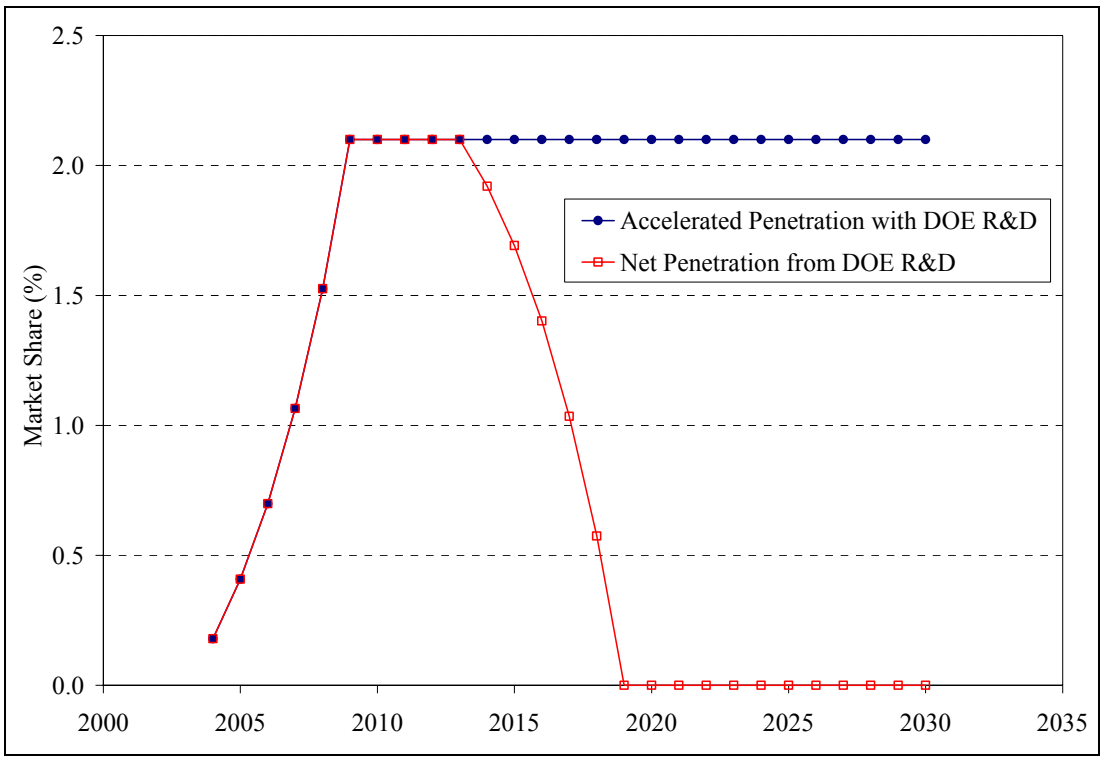

Figure A-11.1. Market Penetration Curve for Residential Can Lights as a Percentage of all Incandescents

R-Lamps

- **Market Introduction:** 2003; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 4 years.
- **Performance Target:** Assumed efficacy of 51.3 lumen/watt. Actual project requirements should be similar to Energy Star, as Table A-11.6 shows. However, because incandescent reflector lamps also have lower efficacies, the ratio between Energy Star compact

fluorescent lamps and all incandescents were assumed to be the same regardless of type. See the Energy Star compact fluorescent lamp summary in Appendix B.

Table A-11.6. Performance Targets for R-Lamps

Lamp Power (watts) and Configuration	Minimum Efficacy: Lumens/watt*
Reflector Lamp:	
Lamp power <20	33
Lamp power >=20	40
* Based on initial lumen date.	

- **Penetration Target:** The goal is to replace 0.87% of all incandescent lighting by 2010. To achieve this goal, an 8.47% sales fraction must be reached with a long-term installed base of 27%, which has consumption roughly equivalent to a 10% installed base in the most energy-intensive fixtures (0.87% = 8.47% * 10.3%). This penetration rate is based on a 4-year compact fluorescent lamp life and a 1-year incandescent reflector life. (The 1-year life for incandescents is longer than the average life of an incandescent lamp; however, integer life inputs are required for BESET, so the ratio between incandescent and fluorescent lights was adjusted appropriately to account for this.) In 2008, 10.3% of the incandescent market will be reflector lights[5] (see Figure A-11.2).
- **Installed Cost:** $14/compact fluorescent lamp reflector lamp.
- **Lifetime:** 8,000 hours (4 years for BESET).

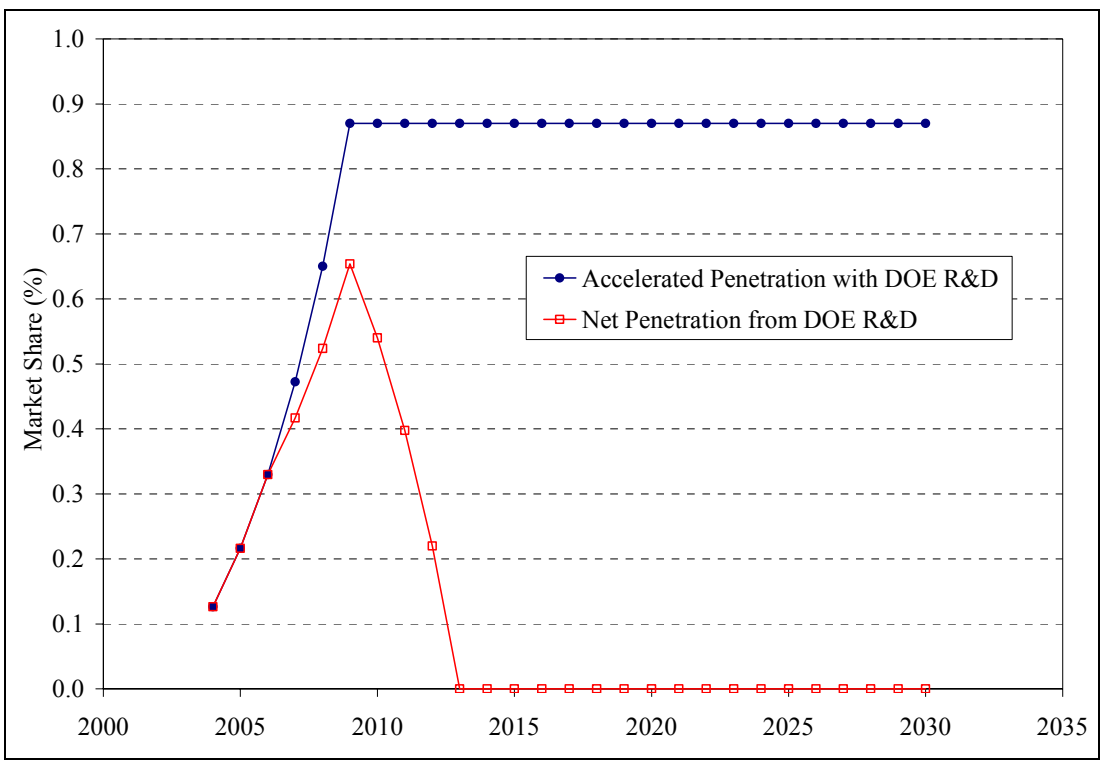

Figure A-11.2. Market Penetration Curve for R-Lamps

A.11 Appliances and Emerging Technologies R&D

Emerging Technologies Decision Unit

Non-Energy Benefits:

- Reduced carbon emissions
- Economic benefits to private sector.

Sources:

(1) FY 2002 Budget Request – *Data Bucket Report for Appliances and Emerging Technology Program* (internal BTS document).

(2) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.

(3) Estimated from http://enduse.lbl.gov/Info/LBNL-39102.pdf, p.19.

(4) Gordon, K.L., and M.R. Ledbetter. 2001. *Technology Procurement Screening Study*. Pacific Northwest National Laboratory, Richland, Washington.

(5) The Freedonia Group, Inc. 1999. *Lamps in the United States to 2003*. Cleveland, Ohio. (See the following sections: "Introduction," "Executive Summary," "Market Environment," "Supply and Demand," "Incandescent Lamps," "Electrical Discharge," and "Lamp Markets.")

A.12 Building Envelope R&D: Window Technologies

Emerging Technologies Decision Unit

Project Objective:[1]

The project's objective is to promote the research and development and deployment of energy-efficient windows. Because the fenestration field is less suited to national standards and has a growing international market, significant investments are needed to establish a technical basis for performance standards recognized for scientific excellence. On this basis, the project helps develop the credible rating, certification projects, and design tools to develop and apply efficient windows. The project also conducts R&D on high-performance windows, including electrochromic technology, and durable spectrally selective glazing.

Long-Term Goals:[1]

The project's specific long-term goals are as follows:

- National: Change windows from net energy losers to net energy providers across the U.S.
- Industry: Strengthen market position of U.S. industry in global markets.
- Owners: Provide cost-effective savings with comfort, productivity, and amenity.

Methodology

PNNL calculated the energy savings for building envelope projects by simulating the effect of an envelope technology using the FEDS[2] model for many different building types, sizes, vintages, and locations and then using NEMS-PNNL to calculate national impacts. PNNL calculated the heating and cooling loads for each building with and without evaluating the envelope technology. We then used the changes in the heating and cooling loads to modify the heating and cooling envelope factors in NEMS-PNNL.

These factors were input as a vector for each building type and census region; these vectors captured both the thermal impact and the expected market penetration by year. Market penetration estimates were based on input from the DOE project manager or representative. Specific project inputs are characterized below for the project's two primary technologies: electrochromic windows and superwindows.

Building Envelope R&D: Window Technologies

Project Type:
Envelope

Target Market:
All sectors in all climate zones

End Uses:
Windows

Unit of Measurement:
Change in heating and cooling loads (based on change in U-factor and shading coefficient)

Modeling Tool:
NEMS-PNNL envelope

Project Manager:
Marc LaFrance

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FY2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
11.5	18.2	70.7	250.4

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.202	0.327	1.31	4.35

Consumer Cost Savings (million $):

2004	2005	2010	2020
78	122	501	1940

A.12 Building Envelope R&D: Window Technologies

Emerging Technologies Decision Unit

Electrochromic Windows[1]

This project develops commercially viable advanced electrochromic windows using competing producers. With a focus on electrochromic research, the project's objective is to reward the marketplace for industry's investments in researching, developing, and deploying energy-efficient windows.

Market Segment:

Performance Objective:

- **Displaced Technology:** Conventional double-glazed, low-emissivity windows.
- **Performance Target:** Reduce unwanted heat gains and losses and perimeter lighting (See Table A-12.1).
- **Performance Parameters:** Estimated savings per building were determined by simulating all commercial building types in all climate zones. National impacts were determined using NEMS-PNNL (Table A-12.1).

Table A-12.1. Performance Targets for Electrochromic Windows

Parameter	Value	Units
Maximum Shading Coefficient	0.4 (heating)	Dimensionless
Minimum Shading Coefficient	0.1 (cooling)	Dimensionless
U-value	0.25	Btu/h • ft^2• ^{o}F
Lighting Reduction	30	% of lighting energy

Target Market

- **Market Description:** [1] The market includes new and existing commercial building types in all climate zones.
- **Size of Market:** ~500 million square feet of windows for commercial buildings.
- **Market Introduction:** The market introduction is targeted for the end of FY 2003 for electrochromic windows in commercial applications. According to a recent study, Electrochromic glazings are currently commercially available in Germany and are anticipated to be available in the US market in 2003[2]. This project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.
- **Market Penetration Goal:** See Table A-12.2.

Table A-12.2. Market Penetration Goals for Electrochromic Windows

Rate of Penetration (% of annual sales)					
Building Type	Vintage	Region	2005	2020	2030
All Commercial	New	All	2.0	20.0	50.0
All Commercial	Existing	All	1.8	17.2	43.2

A.12 Building Envelope R&D: Window Technologies

Emerging Technologies Decision Unit

Project/Technology Consumer Costs:

- **Incremental Cost of BT Technology:** Incremental investment costs were developed assuming a 10-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $10).

Superwindows

The project is developing commercially viable advanced technologies from competing producers and providing research support to Energy Star and Efficient Window Collaborative projects. One project objective is to double the average energy efficiency of windows sold and establish universal National Fenestration Rating Council ratings based on credible International Standards Organization standards.

Market Segment:

Performance Objective:

- **Displaced Technology:** Conventional double-glazed, low-emissivity windows with a U-value of 0.357 Btu/h • ft^2 • ^{o}F and a shading coefficient of 0.52.
- **Performance Target:** Reduce unwanted heat gains and losses.
- **Performance Parameters:** Two superwindow technologies were used: northern superwindows in heating dominated climates (heating-degree days >4500) and southern superwindows in cooling dominated climates (heating-degree days <4500). The estimated savings per building were determined by simulating residential buildings in all climate zones. National impacts were determined using NEMS-PNNL (see Table A-12.3).

Table A-12.3. Performance Targets for Superwindows

Window	Parameter	Value	Units
Northern Superwindow	Shading Coefficient	0.7 (heating season) 0.3 (cooling season)	Dimensionless
	U-value	0.1	Btu/h • ft^2 • ^{o}F
Southern Superwindow	Shading Coefficient	0.15 (all seasons)	Dimensionless
	U-value	0.2	Btu/h • ft^2 • ^{o}F

Target Market

- **Market Description:** [1] New and existing residential units in all climate zones.
- **Size of Market:** [1] ~55 million manufactured units sold each year for residential and light commercial.
- **Market Introduction:** 1999[3]; PNNL assumes that this project accelerates the introduction for these technologies, into the marketplace by 10 years.
- **Market Penetration Goal:** See Table A-12.4.

A.12 Building Envelope R&D: Window Technologies

Emerging Technologies Decision Unit

Table A-12.4. Market Penetration Goals for Superwindows

Rate of Penetration (% of annual sales)					
Building Type	Vintage	Region	2005	2020	2030
Residential	New	All	3.0	65	85.0
Residential	Existing	All	1.5	33	43.2

Project/Technology Consumer Costs:[4]

- **Incremental Cost of BT Technology:** Incremental investment costs were developed assuming a 20-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $20).

Non-Energy Benefits:[1]

- Reduced utility and building peak loads
- Reduced HVAC requirements and first costs
- Improved indoor comfort and aesthetics.

Source:

(1) *FY 2002 Budget Request - Data Bucket Report for Building Envelope: Windows Program* (internal BT document).
(2) Lawrence Berkeley National Laboratory, et. al. 2002. *Active Load Management with Advanced Window Wall Systems: Research and Industry Perspectives.* LBNL-50855. June 2002. Berkeley, California.
(3) Southwall Technologies. "Superglass Quad," product description accessed from website. http://www.southwall.com/products/superglass.html. Accessed March 31, 2003.
(4) Pacific Northwest National Laboratory. 2002. *Facility Energy Decision System User's Guide, Release 5.0.* PNNL-10542, Rev. 6, Richland, Washington.

A.13 Building Envelope R&D: Thermal Insulation and Building Materials

Emerging Technologies Decision Unit

Project Objective:[1]

This project improves envelope performance through advanced technology and increased understanding of the basic processes governing envelope performance. Building envelopes, which influence electric lighting requirements, are the primary factors governing buildings' heating, cooling, and ventilation requirements. Because building envelopes impact 53% of building energy use, improving the materials, components, and systems that make up building envelopes can save substantial energy.

This project performs research on energy-efficient, sustainable, low-cost, and thermal insulation and building envelope materials and structures. The project develops laboratory, analytical, and field experiments and methodologies to characterize tools and testing for new or improved materials and systems. The project also provides accurate evaluation procedures.

Long-Term Goal:[1]

One of the project's long-term goal is to develop new building materials and systems that are cost-competitive for their application and are as environmentally benign and sustainable as possible. Another long-term goal involves developing a fundamental understanding of heat, air, and moisture transfer through building envelopes and insulation materials and applying the results to develop construction technologies to increase building energy efficiency.

Market Segment:

Performance Objective:

- **Displaced Technology:** This project develops technology to displace conventional wall and roof insulation and framing.
- **Performance Target:** The performance target is to reduce unwanted heat gains and losses and perimeter lighting.
- **Performance Parameters:** PNNL estimated savings per building for quick fill walls by simulating food sales, mercantile and service, warehouse, and other commercial building types and single-family residential buildings in all climate zones. For 30/30 roofs, all commercial buildings in all climate zones were considered. We used NEMS-PNNL to determine national impacts. This results in a roof insulation R-value parameter of 30 Btu/h • ft^2 • ^{o}F.

Building Envelope R&D: Thermal Insulation and Building Materials

Project Type:
Envelope

Target Market:
All sectors in all climate zones

End Uses:
Roofs and insulation

Unit of Measurement:
% change in heating and cooling load (based on change in envelope component u-value)

Modeling Tool:
NEMS-PNNL envelope

Project Manager:
Marc LaFrance

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FY2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.2	0.9	9.0	62.1

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.003	0.013	0.136	0.947

Consumer Cost Savings (million $):

2004	2005	2010	2020
1	6	61	419

A.13 Building Envelope R&D: Thermal Insulation and Building Materials

Emerging Technologies Decision Unit

Target Market

- **Market Description:** [1] This project involves developing materials and building envelope structures that can be used in new residential and commercial buildings. Certain project elements also focus on retrofit strategies. The project activities are independent of region and household income.
- **Size of Market:** [1] The market size includes all new and retrofit residential and commercial construction and all building categories.

Methodology

PNNL calculated energy savings for building envelope projects by simulating the effect of an envelope technology using the FEDS[2] model for many different building types, sizes, vintages, and locations and then using NEMS-PNNL to calculate national impacts. We calculated the heating and cooling loads each building with and without evaluating the envelope technology. We then used the heating and cooling load changes to modify the heating and cooling envelope factors in NEMS-PNNL.

These factors were input as a vector for each building type and census region; these vectors captured both the thermal impact and the expected market penetration by year. Market penetration estimates were based on input from the DOE project manager or representative. Specific project inputs are characterized below.

Quick Fill Walls

This technology involves applying environmentally friendly wall-insulating techniques.

Performance Objective:

- **Displaced Technology:** Conventional wall insulation and framing.
- **Performance Target:** Reduce unwanted heat gains and losses and perimeter lighting.
- **Performance Parameters:** Estimated savings per building were determined by simulating food sales, mercantile and service, warehouse, and other commercial building types and single-family residential buildings in all climate zones. National impacts were determined in NEMS-PNNL. This results in a wall insulation parameter of 36 Btu/h • ft^2 • ^oF.

Market Penetration:

- **Target Market:** Selected commercial and residential buildings in all climate zones.
- **Market Introduction:** 2004; this activity was assumed not to occur without DOE funding; therefore, the National Research Council methodology was not applied.
- **Market Penetration Goal:** See Table A-13.1.

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 3-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $3).

A.13 Building Envelope R&D: Thermal Insulation and Building Materials

Emerging Technologies Decision Unit

Table A-13.1. Market Penetration Goals for Quick Fill Walls

Rate of Penetration (% of annual sales)				
Building Type	Vintage	Region	2010	2030
Food Sales, Mercantile and Service, Warehouse, and Other	New	All	1.5	7.6
Residential	New	All	2.3	11.5

R30 Insulation/30-Year Life Roofs

This technology involves applying advanced roofing techniques.

Performance Objective:

- **Displaced Technology:** Conventional roof insulation.
- **Unit of Measurement:** Cooling and heating load reductions for commercial buildings.
- **Performance Target:** Reduce unwanted heat gains and losses. .
- **Performance Parameters:** Estimated savings per building were determined by simulating all commercial building types in all climate zones. National impacts were determined in NEMS-PNNL. This results in a roof insulation R-value parameter of 30 Btu/h • ft^2 • ^oF.

Market Penetration:

- **Target Market:** All sectors in all climate zones.
- **Market Introduction:** 2010; this activity was assumed not to occur without DOE funding; therefore, the National Research Council methodology was not applied.
- **Market Penetration Goal:** See Table A-13.2.

Table A-13.2. Market Penetration Goals for R30 Insulation/30-Year Life Roofs

Rate of Penetration (% of annual sales)				
Building Type	Vintage	Region	2010	2030
All Commercial	New	All	0.6	50.5
All Commercial	Existing	All	0.4	30.2

Project/Technology Consumer Costs (PNNL Estimate):

- **Cost of Conventional Technology:** $0
- **Cost of BT Technology:** $0
- **Incremental Cost:** $0.

Moisture/Wet Insulation

This technology involves developing and applying insulation technology that does not lose its loft or insulating capability after becoming moist/wet and does not cost more than the conventional technology it is replacing.

A.13 Building Envelope R&D: Thermal Insulation and Building Materials

Emerging Technologies Decision Unit

Performance Objective:

- **Performance Target:** Reduce unwanted heat gains and losses by 10%.

Market Penetration

- **Target Market:** All residential buildings in all climate zones.
- **Market Introduction:** 2004; this activity was assumed not to occur without DOE funding; therefore, the National Research Council methodology was not applied.
- **Market Penetration Goal:** See Table A-13.3.

Table A-13.3. Market Penetration Goal for Moisture/Wet Insulation

Rate of Penetration (% of annual sales)					
Building Type	Vintage	Region	2005	2020	2030
Residential	New	All	3.0	65.0	85.0
Residential	Existing	All	1.5	33.0	43.2

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 3-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $3).

Non-Energy Benefits:[1]

- Reduced construction and demolition waste
- Use of natural, recycled, and byproduct materials
- Reduced CO_2 emissions from improved energy efficiency
- Increased housing affordability from reduced energy consumption
- Improved comfort and indoor air quality from more moisture tolerant designs and controls
- Increased global competitiveness of U.S. industry.

Sources:

(1) FY 2002 Budget Request - *Data Bucket Report for Building Envelope: Thermal Insulation and Buildings Materials Program* (internal BTS document).

(2) Pacific Northwest National Laboratory. 2002. *Facility Energy Decision System User's Guide, Release 5.0.* PNNL-10542, Rev. 3, Richland, Washington.

A.14 Analysis Tools and Design Strategies

Emerging Technologies Decision Unit

Project Objective:[1]

The Analysis Tools and Design Strategies project researches the interrelationship of energy systems and buildings energy performance, develops various building analysis tools to more accurately model energy use in new and existing buildings, and provides recommendations and strategies to cost effectively lower energy use and improve building performance. The project focuses on whole-building software tools for evaluating energy efficiency and renewable energy. The project also focuses on nonsoftware solutions such as improved standards, guidelines, and performance measurements, all of which bring about excellence in designing new buildings.

Long-Term Goal:[1]

The project's long-term goal is to improve energy designs for all building types through a number of widely used analytical tools and guidance documents.

Market Segment:

Performance Objective:[2]

- **Displaced Technology:** This technology displaces conventional design/building practice.
- **Performance Target:** By 2020, the performance target is to reduce heating and cooling loads by 50% in new construction and use energy analysis tools in the design of 60% of new commercial building square footage.

Target Market[2]

- **Market Description:** The market includes all new commercial and retrofit construction (particularly buildings with energy-use intensities >50% of the average energy-use intensity).
- **Size of Market:** The market size includes new commercial assembly, education, food sales, food service, lodging, health care, mercantile/service, and office buildings.
- **Market Introduction:** 1996; this activity was assumed not to occur without DOE funding; therefore, the National Research Council methodology (acceleration-to-market) was not applied.

Analysis Tools and Design Strategies

Project Type:
Whole building

Target Market:
New commercial buildings in all climate zones

End Uses:
All end uses and all fuel types

Unit of Measurement:
% change in load

Modeling Tool:
BESET

Project Manager:
Dru Crawley

♦♦♦♦♦♦♦♦♦♦♦♦

FY2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.1	0.3	3.7	41.4

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.002	0.006	0.073	0.757

Consumer Cost Savings (million $):

2004	2005	2010	2020
1	2	24	302

A.14 Analysis Tools and Design Strategies

Emerging Technologies Decision Unit

- **Market Penetration Goal:** The goal is to penetrate 70%[1] of new commercial and multifamily construction by 2020 in combination with the Commercial Buildings Technology R&D project. The share of the market penetration attributed to Analysis Tools and Design Strategies is shown on Figure A-14.1.

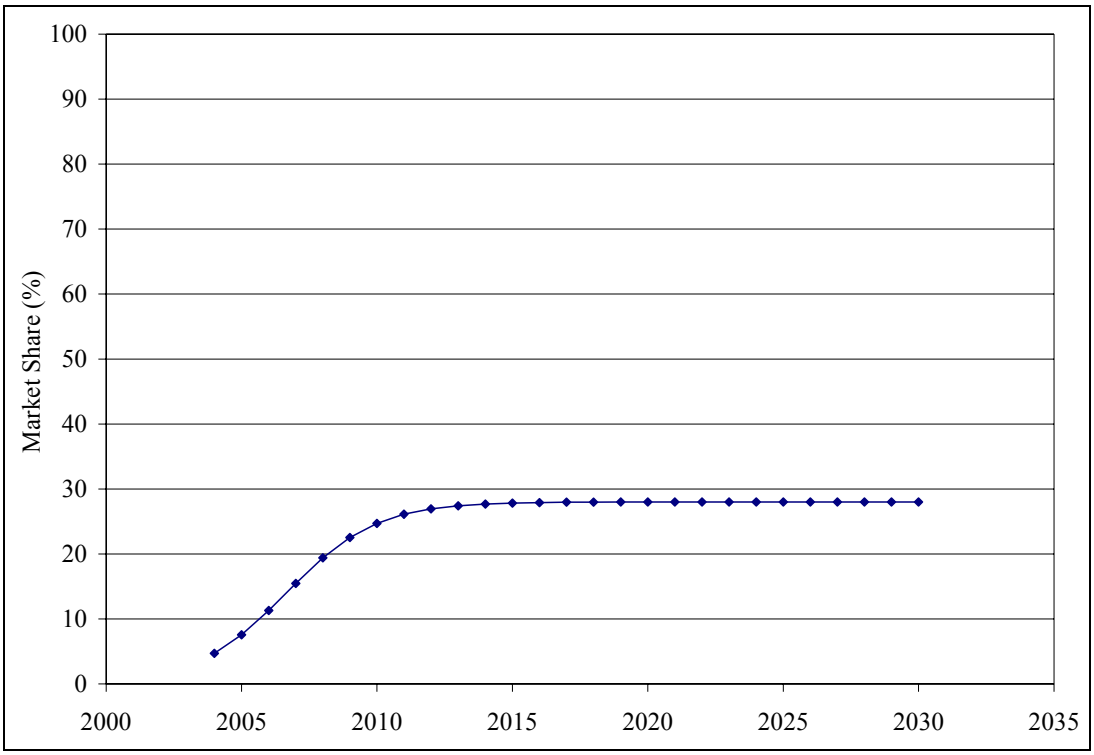

Figure A-14.1. Market Penetration Curve for Analysis Tools and Design Strategies

Methodology

PNNL used BESET to estimate energy savings. To simulate historical penetration rate patterns, we calculated penetration rates for all years before 2030 based on diffusion models, or "S curves" based on historical data. The diffusion models require only the maximum penetration in the final year and the year of entry into the market. Energy technology

[1] In its report, *Energy Research at DOE Was it Worth it?,* the NRC committee concluded that the 25% sustained market penetration estimated for DOE-2 (a software tool previously developed under this project), was overestimated, based on available data (NRC 2001). This conclusion would appear be in conflict with the assumed goals stated for this project. The Analysis Tools and Design Strategies project manager, however, maintains that tools currently in development should achieve the stated penetration goals in combination with the Commercial R&D project.

A.14 Analysis Tools and Design Strategies

Emerging Technologies Decision Unit

diffusion curves were estimated from historical data, and generic curves applicable to future technologies were developed.

Non-Energy Benefits:[1]

- Improved indoor environmental quality such as thermal comfort and ventilation adequacy
- Improved indoor air quality
- Fire safety
- Overall environmental sustainability (i.e., Green Buildings).

Sources:

(1) FY 2002 Budget Request - *Data Bucket Report for Analysis Tools and Design Strategies Program* (internal BTS document).
(2) Interview with the project manager, Dru Crawley, August 22, 2001.

A.15 Equipment Standards and Analysis

Equipment Standards and Analysis

Project Objective:[1]

The Equipment Standards and Analysis project achieves significant energy savings, consumer cost savings, and reduced air emissions through rule-making standards. The project also prescribes test procedures that measure energy efficiency and energy use and that estimate the annual operating cost of each appliance.

Long-Term Goal:[1]

The project's long-term goal is to set minimum national efficiency standards that lead to increases in the average efficiency of new building equipment.

Market Segment:

Target Market

- Market Description: The market includes all residential and commercial equipment covered by the appropriate legislation.[2,3]
- Size of Market: The market size includes all applicable residential and commercial equipment in the market to which legislation applies (Ovens/ranges and medical equipment, for example, are not covered).

Methodology

For FY 2004, the energy savings from equipment standards activities were primarily based on a PNNL screening analysis conducted in late 1999 and early 2000[4] to provide preliminary estimates of the potential energy savings from updated commercial equipment standards. We used the spreadsheet developed for this study to estimate the energy savings from various levels of standards for nearly 40 types of equipment covered by EPAct. The spreadsheet results were used to identify technologies that could achieve significant energy savings beyond the efficiency levels set in the recent ASHRAE 90.1-1999 publication.[5]

For FY 2004, the EPAct standards were assumed to continue with the technologies having the potential for additional energy savings. These technologies include boilers, three-phase residential-size cooling equipment, packaged terminal air conditioning, packaged terminal heat pump equipment, and large rooftop air-conditioning equipment. Energy-savings estimates for these technologies based on the spreadsheet are shown in the next section.

Equipment Standards and Analysis

Project Type:
Codes and standards for equipment efficiency

Target Market:
All sectors in all climate zones

End Uses:
All end uses and all fuel types

Unit of Measurement:
Efficiency of specific equipment

Modeling Tool:
NEMS-PNNL spreadsheet

Project Manager:
Carl Adams

♦♦♦♦♦♦♦♦♦♦♦♦♦

FY2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
0	3.4	83.1	341.2

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.000	0.064	1.657	6.415

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	22	552	2608

A.15 Equipment Standards and Analysis

The FY 2004 savings for this project also included an estimate for revised standards for residential gas furnaces. This project was modeled in the NEMS-PNNL residential module. In the baseline version of the model used by EIA for its *Annual Energy Outlook 2001*,[7] a wide range of the furnace efficiencies was available: 78%, 80%, 84%, 88%, and 96%. To estimate energy savings from this potential standard the 78% and 80% efficiency levels were assumed to not meet the revised standard after 2007. Assuming that the new standard would be set at approximately 82%, an entry with this efficiency level was added to the list of technology options.[m] In addition, savings related to standards covering distribution transformers were calculated in a spreadsheet based on a 1992 study conducted by Geller and Nadel.[7]

Commercial Products

Based on the spreadsheet EPACT_SA.XLS (essentially identical to the spreadsheet installed on the BT website for public comment subsequent to the EPAct screening analysis), Tables A-15.1 and A-15.2 summarize the efficiency assumptions and energy savings results for technologies that DOE/BT will further analyze. The key assumptions and results were summarized for 12 cooling technologies in Table A-15.1 and for boilers and a high-capacity instantaneous water heater in Table A-15.2. Cumulative savings, shown in the last column in both tables, were based on the savings from the effective date of the standards through 2030.

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 9-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $9).

Distribution Transformers

Distribution transformers convert high-voltage electricity from distribution centers to lower-voltage electricity for use at the household level. During this conversion process, a small fraction of heat is lost. Rules are being written to reduce the amount of heat loss during this conversion process.

Savings estimates for a distribution transformer standard were based on a study conducted by Geller and Nadel.[7] The study assumed the following:

- Savings of 80 watts per unit
- See Table A-15.3.
- 20% sales complying with the new level without the standard
- 8,760 annual operating hours per unit
- 13-year life of equipment.

The savings estimate of 80 watts per unit installed was multiplied by the estimated hours of operation and then by the forecasted number of units installed.

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[m] The level is based on a judgmental assessment and should not be construed as representing an official DOE position regarding the potential level at this standard. Analytical work is currently underway to assess the most appropriate level of the standard if a decision to promulgate a new rule is made.

A.15 Equipment Standards and Analysis

Equipment Standards and Analysis

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 10-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $10).

Table A-15.1. Key Assumptions and Results for Cooling Products

Equipment Category	Efficiency (SEER and EER)*			Energy Savings by Year (TBtu)			
	EPAct	New Std	Eff. Date	2010	2020	2030	Cum.
3-Phase Single Package, Air Source Air Conditioning, <65 kBtu/h	9.7	12.0	2005	4.6	21.0	26.5	396.0
3-Phase Single Package, Air Source Heat Pump, <65 kBtu/h	9.7	12.0	2005	1.2	3.1	3.4	60.2
3-Phase Split, Air Source Air Conditioning, <65 kBtu/h	9.7	11.0	2005	0.9	4.1	5.2	78.1
3-Phase Split, Air Source Heat Pump, <65 kBtu/h	9.7	12.0	2005	9.1	24.0	26.5	463.0
Central, Water Source Heat Pump, >17 and <65 kBtu/h	9.3	12.5	2008	1.5	7.1	11.1	146.9
Central, Air Source Air Conditioning, >=65 and <135 kBtu/h	8.9	11.0	2008	5.5	25.0	31.6	471.6
Central, Air Source Air Conditioning, >=135 and <240 kBtu/h	8.5	11.0	2008	5.4	24.6	31.0	463.1
Packaged Terminal Air Conditioning, 7-10 kBtu/h	8.6	10.8	2008	0.4	1.8	2.2	33.3
Packaged Terminal Air Conditioning, 10-13 kBtu/h	8.1	10.2	2008	0.6	2.6	3.3	49.5
* SEER = seasonal energy efficiency ratio; EER = energy efficiency ratio.							

Residential Gas Furnaces

Rules related to the efficiency of residential gas furnaces are being written with the anticipated adoption date of 2008. PNNL estimated savings for residential gas furnaces using NEMS-PNNL and the following assumptions:

- Proposed residential gas furnace efficiency of 82% annual fuel utilization efficiency
- Introduction date of 2008
- Cost of $1400.

Non-Energy Benefits:[1]

- Reduced CO_2 and SO_X emissions

A.15 Equipment Standards and Analysis

- Reduced water consumption from plumbing equipment
- Increased life of equipment operating at cooler temperatures
- Reduced first costs that transform new technologies into commodities.

Table A-15.2. Key Assumptions and Results for Boilers and a High-Capacity Instantaneous Water Heater

Equipment Category	Efficiency (SEER and EER)			Energy Savings by Year (TBtu)			
	EPAct	New Std	Eff. Date	2010	2020	2030	Cum.
Pkg'd Boilers, Gas, 400 kBtu/h, Hot Water	75%	78%	2008	0.2	0.9	1.7	19.7
Pkg'd Boilers, Gas, 800 kBtu/h, Hot Water	75%	78%	2008	0.4	2.0	3.7	43.0
Pkg'd Boilers, Gas, 1500 kBtu/h, Hot Water	75%	78%	2008	0.1	0.7	1.2	14.2
Pkg'd Boilers, Gas, 3000 kBtu/h, HW	75%	80%	2008	0.2	0.7	1.3	15.2
Pkg'd Boilers, Gas, 400 kBtu/h, Steam	72%	76%	2008	0.1	0.6	1.1	12.6
Pkg'd Boilers, Gas, 800 kBtu/h, Steam	72%	76%	2008	0.4	1.6	3.0	34.5
Pkg'd Boilers, Gas, 1500 kBtu/h, Steam	72%	79%	2008	0.3	1.2	2.3	26.7
Pkg'd Boilers, Gas, 3000 kBtu/h, Steam	72%	80%	2008	0.2	0.9	1.7	19.2
Instantaneous Water Heaters, 1000 kBtu/h	80%	83%	2008	1.0	4.4	5.6	83.3

A.15 Equipment Standards and Analysis

Table A-15.3. Distribution Transformer Market Penetration

Year	Transformer Sales Forecast
2004	1,592,533
2005	1,623,086
2006	1,654,225
2007	1,685,962
2008	1,718,307
2009	1,751,273
2010	1,784,871
2011	1,819,115
2012	1,854,015
2013	1,889,584
2014	1,925,836
2015	1,962,784
2016	2,000,440
2017	2,038,819
2018	2,077,934
2019	2,117,799
2020	2,158,429
2021	2,199,839
2022	2,242,044
2023	2,285,057
2024	2,328,057
2025	2,373,577
2026	2,419,114
2027	2,465,525
2028	2,512,827
2029	2,561,036
2030	2,610,170

Sources:

(1) FY 2002 Budget Request - *Data Bucket Report for the Lighting and Appliance Standards Program* (internal BTS document).

(2) National Appliance Energy Conservation Act of 1987, Public Law 100-12.

(3) Energy Policy Act of 1992, Public Law 102-486.

(4) Somasundaran, S. et al. 2000. *Screening Analysis of EPAct-Covered Commercial HVAC and Water Heating Equipment*. PNNL-13232, Pacific Northwest National Laboratory, Richland, Washington..

(5) ASHRAE 90.1-1999, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

(6) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.

A.15 Equipment Standards and Analysis

(7) Geller, H., and S. Nadel. 1992. "Consensus National Efficiency Standards for Lamps, Motors, Showerheads and Faucets, and Commercial HVAC Equipment." In *American Council for an Energy Efficient Economy Proceedings*, pp. 6.71-6.82.

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Appendix B – Weatherization and Intergovernmental Program

This appendix describes the results of the forecasted energy savings, consumer cost savings, and carbon benefits for each of the 12 WIP projects (for 2004, 2005, 2010, and 2020). Tables show forecasted benefits up to the year 2030 for all projects and decision units. The projects for WIP are also summarized in this appendix.

B.1 Energy Savings Analysis by Decision Unit

Decision unit benefits are reported annually. The energy savings estimates for 2010 represent energy saved in 2010 only; these are not cumulative benefits estimates. However, the energy savings in 2010 are a function of all project activities from FY 2004 on, so the number of affected buildings is a cumulative value. For example, for the ENERGY STAR CFLs, the energy saved in 2010 is the energy saved in 2010 only, from all buildings that have had such lights installed any time between FY 2004 and FY 2010.

Table B-1.1 summarizes the primary energy savings, the carbon equivalent reductions, and the consumer cost savings for the three WIP decision units.

Table B-1.1. Summary of Benefits: Analyses of WIP Projects

Decision Unit	FY 2004 Budget Request (Million $)	2004	2005	2010	2020
Primary Energy Savings (TBtu/Yr)					
Weatherization Assistance Project	288	8.6	16.9	57.6	122.5
State Energy Project	39	4.0	7.8	24.7	48.7
Gateway Deployment	18	39.2	73.4	271.6	975.6
Totals		51.8	98.2	353.9	1146.7
Carbon Equivalent Emission Reductions (MMTCE/Yr)					
Weatherization Assistance Project	288	0.1	0.3	1.0	2.0
State Energy Project	39	0.1	0.1	0.5	0.9
Gateway Deployment	18	0.7	1.3	5.3	18.5
Totals		0.9	1.7	6.8	21.4
Consumer Cost Savings (Million $/yr)					
Weatherization Assistance Project	288	60.0	117.0	411.0	917.0
State Energy Project	39	25.0	48.0	158.0	352.0
Gateway Deployment	18	259.0	479.0	2031.0	8611.0
Totals		344.0	643.0	2600.0	9880.0

Total primary energy savings for all WIP projects are estimated to reach 0.4 QBtu by year 2010 and 1.1 QBtu by year 2020. Figure B-1.1 charts annual energy savings for all WIP projects for the years FY 2004 to FY 2020. In the short-term, roughly half of the savings are generated in the residential sector and half in the commercial sector; however, in later years, relatively more energy savings (roughly two-thirds) are estimated to come from the residential sector.

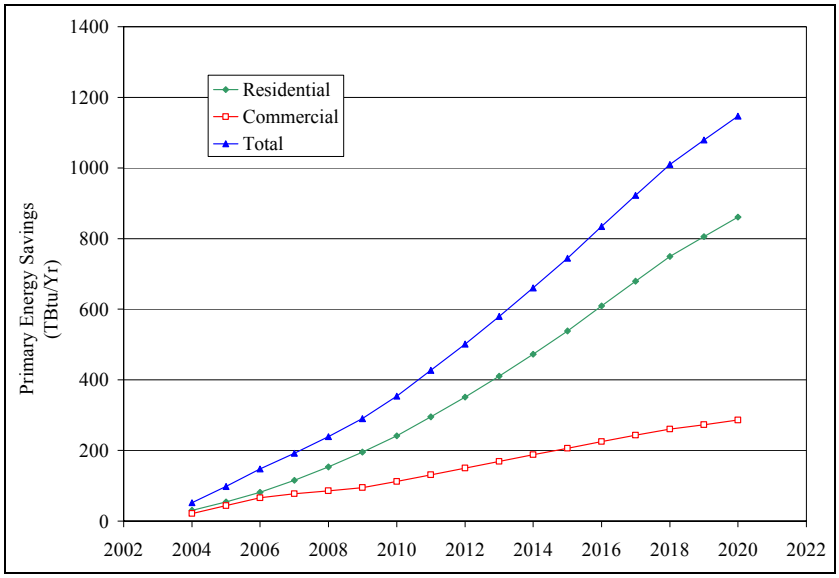

Figure B-1.1. WIP Primary Energy Savings by Sector through FY 2020

Figure B-1.2 compares the BT and WIP primary energy savings projections with building energy consumption forecasts from the *Annual Energy Outlook 2002*. The FY 2004 estimates include only savings for projects that are included in the FY 2004 WIP funding request. Some activities funded in previous years may contribute to total WIP future energy savings but are *not* in the FY 2004 request. For example, a project that supports a rulemaking that is completed in FY 2003 would not be included in the FY 2004 request; however, this project would produce energy savings in future years.

Figure B-1.2 shows savings for FY 2004 projects as well as projects that have been retired since FY 2000 but have future energy savings. The projections of WIP and BT project savings are charted relative to the building energy consumption forecasts generated by *Annual Energy Outlook 2002*. Figure B-1.2 shows that if the forecasted savings generated by WIP and BT projects are subtracted from forecasted total building energy use, total primary building energy use remains relatively flat through 2020.

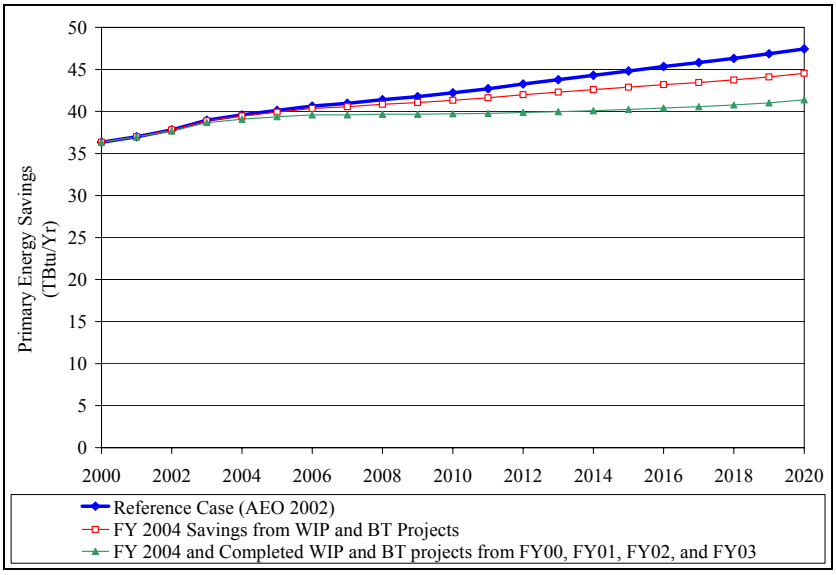

Figure B-1.2. Building Energy Consumption with and without BT/WIP Savings

Of all WIP energy savings (in year 2020), projects included in the Gateway Deployment decision unit generate 85% of the total savings (see Figure B-1.3). This decision unit includes information/education (e.g., Information Outreach), training (e.g., Building Codes Training), and market transformation (e.g., ENERGY STAR) projects. Gateway Deployment makes up ~5% of the overall WIP project FY 2004 budget. Weatherization Assistance makes up ~11% of the total savings while accounting for ~83% of the total budget request. The State Energy project decision unit makes up ~4% of the overall savings and accounts for 11% of the overall budget.

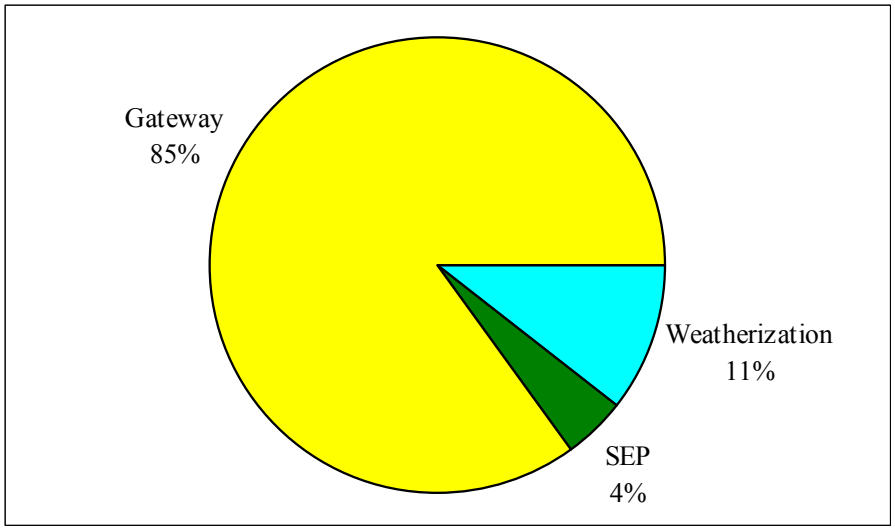

Figure B-1.3. WIP Primary Energy Savings by Decision Unit (for 2020)

In terms of energy savings per budget dollar, the Building Codes Training and Assistance project and ENERGY STAR have relatively high ratios of savings to budget dollar. The Building Energy Codes project benefits from having high penetration rates because the building codes upon which these estimates are based become regulatory mandates when adopted by states. ENERGY STAR focuses on market transformation through labeling and requires relatively few dollars to implement compared with projects that provide R&D or technical assistance. Projects such as Weatherization and State Energy tend to have relatively low ratios of savings to budget dollar because these projects provide grants and assistance directly to states and households. Figure B-1.4 charts the FY 2004 final budget request and the energy savings of each decision unit.

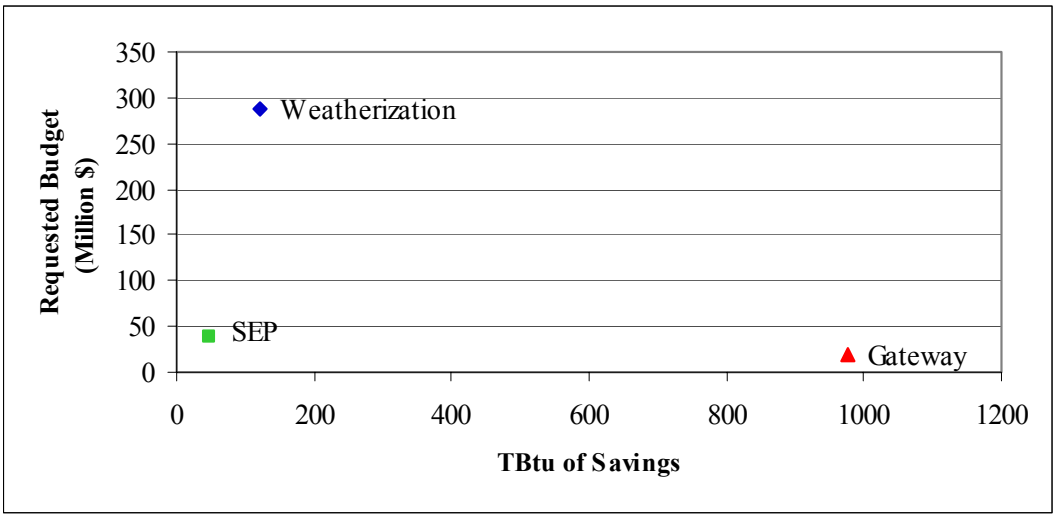

Figure B-1.4. Budget and Energy Savings Scatter Plot for WIP Decision Unit [a]

B.2 FY 2004 GPRA Metrics for WIP Based on FY 2004 WIP Budget Request

This section summarizes the GPRA metrics benefits estimates produced for WIP and submitted to PBFA as part of EERE's FY 2004 GPRA metrics effort. These estimates were produced in conjunction with the draft WIP FY 2004 budget request (dated February 3, 2003) and represent the expected benefits from project activities funded under the FY 2004 budget request. Benefits resulting from funding in years before FY 2004 are not included. Benefits accruing from future funding are included in the estimates.

B.2.1 Scope of Analysis

The benefits estimates are developed based on a series of assumptions developed project-by-project and documented in sections B.3 through B.8. These input assumptions are critical to the analysis and are developed through an iterative process with the Project Managers. It should be noted that because WIP projects are in different stages of maturity, there are varying degrees of corroborative studies available on which project information can be substantiated. Additionally, newer projects may not have estimates of future costs well-coordinated with performance estimates. For example, research projects would be expected to have more tenuous estimates of price and performance characteristics of potential products than deployment-related projects that feature products closer to market adoption. PNNL recognizes the varying levels of maturity and distance from market across projects and that the cost and performance characteristics improve as projects mature or as they near commercialization.

[a] Benefits estimates for both the State Energy Project and Weatherization Assistance include those resulting from activities using non-DOE (leveraged) funding. For FY 2004, an additional $155 million is assumed to be leveraged for SEP activities, and an additional $300 million is assumed to be leveraged for use in weatherization activities. See sections B.3 and B.4 for further details.

B.2.2 Comparison of FY 2003 GPRA Metrics with FY 2004 GPRA Metrics[b]

Energy savings estimates are reported to PBFA at a decision unit level; however, this section explains changes that arise at the individual project/technology level. While estimates at the project level are not reported to PBFA as part of the GPRA metrics, they provide a useful planning tool for WIP and variations should be understood.

Overall, the estimated energy savings from WIP projects through 2020 are lower in the early years than those associated with the FY 2003 request. The FY 2003 estimate of 0.46 QBtu in 2010 has fallen to 0.35 QBtu in the FY 2004 estimate. By 2020, the FY 2004 estimates have risen so that the FY 2004 estimate of primary savings in 2020 is slightly higher, increasing from 1.09 QBtu in the FY 2003 estimate to 1.14 QBtu.

The discussion has been divided into five categories relative to primary energy savings in the year 2020. Any other projects not mentioned did not result in any change in out-year primary energy savings estimates.

1. Projects characterized in FY 2003 but not in FY 2004
2. Projects that have not changed significantly between FY 2003 and FY 2004
3. Projects that have changed 25% to 50% between FY 2003 and FY 2004
4. Projects that have changed more than 50% between FY 2003 and FY 2004
5. Projects characterized in FY 2004 but not in FY 2003.

Projects that fall into the first category have been completed or terminated and are not in the FY 2004 request. Projects that fall into the fifth category were not characterized in the FY 2003 metrics because either they were new to the FY 2004 request or not enough information was available about them in FY 2003 to characterize them.

In general, projects are included in GPRA based on whether they are a line item in the initial budget request with a specific funding allocation. Occasionally, projects do not appear as a line item in the initial funding request but do appear in the final request. These projects are characterized within GPRA metrics only if enough information is available to characterize the project in a short period of time. For projects covering a suite of technologies, the technologies characterized are based on discussions with the project manager. The suites of technologies may change from year to year as the project manager changes focus. The suite of technologies is meant to represent the project not to capture all funded activities. The impact of these categories of projects is discussed below and shown in Table B-2.1:

- Projects characterized in FY 2003 but not in FY 2004 – No WIP projects or activities were assumed to be completed or terminated between FY 2003 and FY 2004.

- Projects that have not changed significantly between FY 2003 and FY 2004 – The modeling methods or characterizations for four WIP projects or technologies did not change significantly between FY 2003 and FY 2004:
  - State Energy Project
  - Rebuild America
  - Training and Technical Assistance for Codes

[b] FY 2003 GPRA Metrics based on BESET Run 4N; FY 2004 GPRA Metrics based on BESET Run 5.

- Energy Star: CFLs.

- Projects that have changed 25% to 50% between FY 2003 and FY 2004 – The Information Outreach project decreased ~28 TBtu in 2020 because of a significant budget request decrease.

- Projects that have changed more than 50% between FY 2003 and FY 2004 – No WIP projects fell into this category.

- Projects characterized in FY 2004 but not in FY 2003 – No projects fell into this category.

Table B-2.1. Impact of WIP Project Changes

Changes by Category	Year 2020 (TBtu)
FY 2003 Estimate	1,091
Less	
1. Projects characterized in FY 2003 but not in FY 2004	0
Plus	
2. Projects that have not changed significantly between FY 2003 and FY 2004	83
3. Projects that have changed 25% to 50% between FY 2003 and FY 2004	- 28
4. Projects that have changed more than 50% between FY 2003 and FY 2004	0
5. Projects characterized in FY 2004 but not in FY 2003	0
Equals	
FY 2004 Estimate	1,147

B.2.3 FY 2004 GPRA Metrics – Detailed Tables

Tables B-2.2 through B-2.19 are included here to show forecasted benefits up to the year 2030 for all projects and decision units. The benefit estimates available include:

- Energy Savings Benefits Tables (TBtu per year)
  - Total Primary Energy Savings
  - Total Site Energy Savings
  - Primary Electricity Energy Savings
  - Primary Non-Electric Energy Savings
  - Site Electricity Energy Savings
  - Site Natural Gas Energy Savings
  - Site Fuel Oil Energy Savings

- Environmental Benefits Tables (million metric tons per year)
  - Carbon Equivalent Emissions Reductions
  - SO_2 Emissions Reductions
  - NO_X Emissions Reductions
  - CO Emissions Reductions

- PM Emissions Reductions
- VOC Emissions Reductions

- Financial Benefits Tables (million $ per year)
  - Consumer Cost Savings
  - Non-Energy Cost Savings
  - Incremental Private Investment

- Employment and Income Impacts Tables (from ImBuild)
  - Employment Impacts, Savings Only (thousand jobs per year)
  - Income Impacts, Savings Only (million $ per year).

Project benefits are reported annually in the tables. The energy savings estimate for 2010 represents energy saved in 2010 only. These are not cumulative benefits estimates. However, the energy saved in 2010 is a function of all project activities from FY 2004 on, so that the number of affected buildings is a cumulative value. For example, the energy saved in 2010 from the CFLs (within Energy Star) is the energy saved in 2010 only, from all buildings that have had such lights installed any time between 2004 and 2010.

Reductions in emissions from WIP projects are calculated from GPRA metrics estimates of energy savings by fuel type, multiplied by emissions coefficients provided by PBFA for the GPRA metrics.

The consumer cost savings estimates are calculated from GPRA metrics estimates of energy savings by sector and fuel type, multiplied by energy price forecasts provided by PBFA for the GPRA metrics.

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.2. Primary Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**8.6**	**16.9**	**25.1**	**33.5**	**41.6**	**57.6**	**98.1**	**122.5**	**123.5**	**123.5**
Weatherization Assistance	8.6	16.9	25.1	33.5	41.6	57.6	98.1	122.5	123.5	123.5
2 State Energy Project	**4.0**	**7.8**	**11.5**	**15.2**	**18.6**	**24.7**	**40.1**	**48.7**	**48.7**	**48.7**
State Energy Project	4.0	7.8	11.5	15.2	18.6	24.7	40.1	48.7	48.7	48.7
3 Gateway Deployment	**39.2**	**73.4**	**110.8**	**143.5**	**178.8**	**271.6**	**606.5**	**975.6**	**1,238.7**	**1,413.0**
Rebuild America	1.6	3.0	5.1	8.2	10.8	16.7	21.8	20.8	20.9	21.1
Energy Efficiency Information Outreach	14.6	29.0	42.3	42.2	41.1	39.2	37.1	36.0	36.0	36.0
Building Codes Training and Assistance	4.7	11.1	18.4	27.9	38.0	72.0	201.4	320.7	427.4	525.9
Energy Star: Clothes Washers	13.5	17.9	22.0	26.5	30.5	37.8	51.3	63.9	78.6	94.6
Energy Star: Refrigerators	0.4	1.0	1.8	3.0	4.0	5.8	10.0	13.0	17.0	21.5
Energy Star: Electric Water Heaters	0.1	0.5	1.1	2.3	4.6	12.9	32.8	55.4	83.2	115.1
Energy Star: Gas Water Heaters	0.0	0.1	0.2	0.4	0.7	1.5	4.3	10.5	17.3	24.7
Energy Star: Room Air Conditioners	0.3	0.6	0.8	1.0	1.2	1.5	2.3	3.1	4.1	5.3
Energy Star: CFLs	3.7	10.0	18.5	31.1	46.8	82.9	243.0	448.6	549.2	562.3
Energy Star: Dishwashers	0.2	0.4	0.7	0.8	1.0	1.4	2.4	3.5	4.9	6.5
Weatherization and Intergovernmental Activities Total	**51.8**	**98.2**	**147.4**	**192.2**	**238.9**	**353.9**	**744.7**	**1,146.7**	**1,410.9**	**1,585.1**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.3. Site Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**7.2**	**14.1**	**21.2**	**28.3**	**35.4**	**49.9**	**86.4**	**108.9**	**109.8**	**109.8**
Weatherization Assistance	7.2	14.1	21.2	28.3	35.4	49.9	86.4	108.9	109.8	109.8
2 State Energy Project	**2.1**	**4.2**	**6.4**	**8.5**	**10.6**	**14.8**	**25.4**	**31.8**	**31.8**	**31.8**
State Energy Project	2.1	4.2	6.4	8.5	10.6	14.8	25.4	31.8	31.8	31.8
3 Gateway Deployment	**20.2**	**36.4**	**55.0**	**68.8**	**85.8**	**133.0**	**299.9**	**488.4**	**622.5**	**720.0**
Rebuild America	1.1	1.9	3.4	5.4	7.3	11.6	15.8	15.2	15.2	15.2
Energy Efficiency Information Outreach	7.9	15.8	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6
Building Codes Training and Assistance	1.7	3.8	6.4	9.8	14.4	31.5	101.0	169.3	228.8	284.6
Energy Star: Clothes Washers	8.1	10.8	13.7	16.6	19.5	25.3	36.0	46.2	57.1	68.8
Energy Star: Refrigerators	0.1	0.3	0.6	1.0	1.4	2.2	4.1	5.6	7.3	9.3
Energy Star: Electric Water Heaters	0.0	0.2	0.4	0.8	1.6	4.9	13.6	24.0	36.0	49.8
Energy Star: Gas Water Heaters	0.0	0.1	0.2	0.4	0.7	1.5	4.3	10.5	17.3	24.7
Energy Star: Room Air Conditioners	0.1	0.2	0.3	0.3	0.4	0.6	1.0	1.4	1.8	2.3
Energy Star: CFLs	1.2	3.2	6.2	10.5	16.4	31.3	99.6	191.1	233.2	238.7
Energy Star: Dishwashers	0.1	0.1	0.2	0.3	0.4	0.5	1.0	1.5	2.1	2.8
Weatherization and Intergovernmental Activities Total	**29.5**	**54.8**	**82.5**	**105.5**	**131.7**	**197.7**	**411.8**	**629.1**	**764.0**	**861.5**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.4. Primary Electricity Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**2.2**	**4.2**	**6.0**	**8.0**	**9.6**	**12.5**	**19.9**	**23.9**	**24.1**	**24.1**
Weatherization Assistance	2.2	4.2	6.0	8.0	9.6	12.5	19.9	23.9	24.1	24.1
2 State Energy Project	**2.7**	**5.3**	**7.7**	**10.2**	**12.3**	**15.9**	**25.0**	**29.9**	**29.9**	**29.9**
State Energy Project	2.7	5.3	7.7	10.2	12.3	15.9	25.0	29.9	29.9	29.9
3 Gateway Deployment	**27.8**	**54.6**	**84.2**	**112.8**	**143.2**	**223.1**	**522.5**	**859.0**	**1,086.6**	**1,222.0**
Rebuild America	0.9	1.6	2.6	4.2	5.4	8.1	10.3	9.9	10.1	10.4
Energy Efficiency Information Outreach	9.9	19.5	28.1	28.0	27.0	25.0	22.9	21.8	21.8	21.8
Building Codes Training and Assistance	4.3	10.7	18.2	27.4	36.3	65.2	171.2	267.0	350.2	425.5
Energy Star: Clothes Washers	8.0	10.4	12.5	15.0	16.9	20.2	26.1	31.1	37.9	45.5
Energy Star: Refrigerators	0.4	1.0	1.8	3.0	4.0	5.8	10.0	13.0	17.0	21.5
Energy Star: Electric Water Heaters	0.1	0.5	1.1	2.3	4.6	12.9	32.8	55.4	83.2	115.1
Energy Star: Gas Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Room Air Conditioners	0.3	0.6	0.8	1.0	1.2	1.5	2.3	3.1	4.1	5.3
Energy Star: CFLs	3.7	10.0	18.5	31.1	46.8	83.1	244.5	454.1	557.3	570.5
Energy Star: Dishwashers	0.2	0.4	0.7	0.8	1.0	1.4	2.4	3.5	4.9	6.5
Weatherization and Intergovernmental Activities Total	**32.7**	**64.0**	**97.9**	**131.0**	**165.1**	**251.6**	**567.4**	**912.8**	**1,140.6**	**1,276.0**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.5. Primary Non-Electric Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**6.5**	**12.8**	**19.2**	**25.6**	**32.0**	**45.1**	**78.2**	**98.6**	**99.4**	**99.4**
Weatherization Assistance	6.5	12.8	19.2	25.6	32.0	45.1	78.2	98.6	99.4	99.4
2 State Energy Project	**1.3**	**2.5**	**3.8**	**5.0**	**6.3**	**8.8**	**15.1**	**18.8**	**18.8**	**18.8**
State Energy Project	1.3	2.5	3.8	5.0	6.3	8.8	15.1	18.8	18.8	18.8
3 Gateway Deployment	**11.4**	**18.8**	**26.6**	**30.6**	**35.5**	**48.5**	**84.0**	**116.6**	**152.1**	**190.9**
Rebuild America	0.8	1.4	2.5	4.0	5.4	8.6	11.5	11.0	10.8	10.7
Energy Efficiency Information Outreach	4.7	9.5	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
Building Codes Training and Assistance	0.3	0.4	0.2	0.5	1.7	6.8	30.3	53.7	77.2	100.4
Energy Star: Clothes Washers	5.5	7.5	9.5	11.5	13.6	17.6	25.2	32.8	40.7	49.1
Energy Star: Refrigerators	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Electric Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Gas Water Heaters	0.0	0.1	0.2	0.4	0.7	1.5	4.3	10.5	17.3	24.7
Energy Star: Room Air Conditioners	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: CFLs	0.0	0.0	0.0	0.0	0.0	-0.1	-1.5	-5.5	-8.1	-8.2
Energy Star: Dishwashers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weatherization and Intergovernmental Activities Total	**19.1**	**34.1**	**49.5**	**61.2**	**73.8**	**102.4**	**177.3**	**234.0**	**270.3**	**309.1**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.6. Site Electricity Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.7**	**1.3**	**2.0**	**2.7**	**3.4**	**4.7**	**8.2**	**10.4**	**10.4**	**10.4**
Weatherization Assistance	0.7	1.3	2.0	2.7	3.4	4.7	8.2	10.4	10.4	10.4
2 State Energy Project	**0.9**	**1.7**	**2.6**	**3.4**	**4.3**	**6.0**	**10.3**	**12.9**	**12.9**	**12.9**
State Energy Project	0.9	1.7	2.6	3.4	4.3	6.0	10.3	12.9	12.9	12.9
3 Gateway Deployment	**8.8**	**17.6**	**28.4**	**38.1**	**50.3**	**84.5**	**215.9**	**371.9**	**470.4**	**529.0**
Rebuild America	0.3	0.5	0.9	1.4	1.9	3.1	4.2	4.3	4.4	4.5
Energy Efficiency Information Outreach	3.2	6.3	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Building Codes Training and Assistance	1.4	3.4	6.1	9.3	12.7	24.7	70.7	115.6	151.6	184.2
Energy Star: Clothes Washers	2.6	3.4	4.2	5.1	5.9	7.7	10.8	13.5	16.4	19.7
Energy Star: Refrigerators	0.1	0.3	0.6	1.0	1.4	2.2	4.1	5.6	7.3	9.3
Energy Star: Electric Water Heaters	0.0	0.2	0.4	0.8	1.6	4.9	13.6	24.0	36.0	49.8
Energy Star: Gas Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Room Air Conditioners	0.1	0.2	0.3	0.3	0.4	0.6	1.0	1.4	1.8	2.3
Energy Star: CFLs	1.2	3.2	6.2	10.5	16.4	31.5	101.0	196.6	241.3	247.0
Energy Star: Dishwashers	0.1	0.1	0.2	0.3	0.4	0.5	1.0	1.5	2.1	2.8
Weatherization and Intergovernmental Activities Total	**10.4**	**20.7**	**33.0**	**44.3**	**57.9**	**95.3**	**234.4**	**395.1**	**493.8**	**552.4**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.7. Site Natural Gas Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**4.6**	**9.0**	**13.5**	**18.0**	**22.6**	**31.8**	**55.2**	**69.5**	**70.1**	**70.1**
Weatherization Assistance	4.6	9.0	13.5	18.0	22.6	31.8	55.2	69.5	70.1	70.1
2 State Energy Project	**0.3**	**0.5**	**0.8**	**1.0**	**1.3**	**1.8**	**3.0**	**3.8**	**3.8**	**3.8**
State Energy Project	0.3	0.5	0.8	1.0	1.3	1.8	3.0	3.8	3.8	3.8
3 Gateway Deployment	**10.0**	**16.6**	**23.5**	**26.9**	**31.1**	**42.3**	**73.5**	**102.6**	**134.7**	**170.2**
Rebuild America	0.7	1.3	2.3	3.7	5.0	8.0	10.7	10.2	10.1	10.1
Energy Efficiency Information Outreach	4.3	8.7	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Building Codes Training and Assistance	0.2	0.2	-0.2	-0.1	0.7	4.8	24.9	45.2	65.8	86.2
Energy Star: Clothes Washers	4.7	6.4	8.2	9.9	11.7	15.3	22.1	29.0	36.3	44.2
Energy Star: Refrigerators	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Electric Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Gas Water Heaters	0.0	0.1	0.2	0.4	0.7	1.5	4.3	10.5	17.3	24.7
Energy Star: Room Air Conditioners	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: CFLs	0.0	0.0	0.0	0.0	0.0	-0.1	-1.4	-5.3	-7.9	-8.0
Energy Star: Dishwashers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weatherization and Intergovernmental Activities Total	**14.8**	**26.2**	**37.8**	**46.0**	**54.9**	**75.9**	**131.7**	**175.8**	**208.5**	**244.0**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.8. Site Fuel Oil Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**1.9**	**3.8**	**5.7**	**7.6**	**9.5**	**13.3**	**23.1**	**29.1**	**29.3**	**29.3**
Weatherization Assistance	1.9	3.8	5.7	7.6	9.5	13.3	23.1	29.1	29.3	29.3
2 State Energy Project	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**7.0**	**12.0**	**15.1**	**15.1**	**15.1**
State Energy Project	1.0	2.0	3.0	4.0	5.0	7.0	12.0	15.1	15.1	15.1
3 Gateway Deployment	**1.4**	**2.2**	**3.1**	**3.7**	**4.4**	**6.1**	**10.5**	**14.0**	**17.4**	**20.8**
Rebuild America	0.1	0.1	0.2	0.3	0.4	0.6	0.8	0.7	0.7	0.7
Energy Efficiency Information Outreach	0.4	0.8	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Building Codes Training and Assistance	0.1	0.2	0.4	0.6	1.0	2.0	5.4	8.5	11.4	14.2
Energy Star: Clothes Washers	0.8	1.1	1.3	1.6	1.8	2.3	3.1	3.8	4.4	5.0
Energy Star: Refrigerators	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Electric Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Gas Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Room Air Conditioners	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: CFLs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.2	-0.2
Energy Star: Dishwashers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weatherization and Intergovernmental Activities Total	**4.3**	**8.0**	**11.8**	**15.3**	**18.9**	**26.5**	**45.6**	**58.2**	**61.8**	**65.1**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.9. Carbon Equivalent Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.143**	**0.282**	**0.422**	**0.570**	**0.707**	**0.977**	**1.645**	**2.040**	**2.057**	**2.057**
Weatherization Assistance	0.143	0.282	0.422	0.570	0.707	0.977	1.645	2.040	2.057	2.057
2 State Energy Project	**0.073**	**0.147**	**0.219**	**0.300**	**0.367**	**0.490**	**0.779**	**0.933**	**0.933**	**0.933**
State Energy Project	0.073	0.147	0.219	0.300	0.367	0.490	0.779	0.933	0.933	0.933
3 Gateway Deployment	**0.673**	**1.307**	**2.031**	**2.746**	**3.451**	**5.305**	**11.662**	**18.467**	**23.426**	**26.638**
Rebuild America	0.027	0.051	0.088	0.144	0.190	0.292	0.375	0.354	0.355	0.360
Energy Efficiency Information Outreach	0.249	0.507	0.755	0.777	0.759	0.722	0.666	0.636	0.636	0.636
Building Codes Training and Assistance	0.084	0.207	0.358	0.566	0.768	1.445	3.871	6.014	7.987	9.801
Energy Star: Clothes Washers	0.228	0.309	0.386	0.478	0.550	0.681	0.899	1.097	1.348	1.618
Energy Star: Refrigerators	0.007	0.018	0.035	0.061	0.081	0.119	0.199	0.253	0.330	0.418
Energy Star: Electric Water Heaters	0.002	0.009	0.021	0.047	0.095	0.265	0.653	1.077	1.619	2.239
Energy Star: Gas Water Heaters	0.000	0.001	0.003	0.006	0.010	0.021	0.061	0.151	0.249	0.356
Energy Star: Room Air Conditioners	0.006	0.010	0.016	0.020	0.024	0.030	0.047	0.061	0.080	0.103
Energy Star: CFLs	0.067	0.187	0.357	0.630	0.952	1.701	4.843	8.756	10.726	10.981
Energy Star: Dishwashers	0.003	0.007	0.013	0.017	0.021	0.029	0.048	0.068	0.096	0.127
Weatherization and Intergovernmental Activities Total	**0.889**	**1.736**	**2.672**	**3.615**	**4.525**	**6.773**	**14.086**	**21.440**	**26.416**	**29.628**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.10. SO_2 Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.001**	**0.003**	**0.005**	**0.006**	**0.008**	**0.011**	**0.018**	**0.022**	**0.022**	**0.022**
Weatherization Assistance	0.001	0.003	0.005	0.006	0.008	0.011	0.018	0.022	0.022	0.022
2 State Energy Project	**0.001**	**0.002**	**0.004**	**0.005**	**0.006**	**0.009**	**0.013**	**0.016**	**0.016**	**0.016**
State Energy Project	0.001	0.002	0.004	0.005	0.006	0.009	0.013	0.016	0.016	0.016
3 Gateway Deployment	**0.006**	**0.014**	**0.024**	**0.037**	**0.047**	**0.073**	**0.153**	**0.233**	**0.294**	**0.332**
Rebuild America	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.003	0.003	0.003
Energy Efficiency Information Outreach	0.002	0.005	0.008	0.009	0.009	0.008	0.007	0.006	0.006	0.006
Building Codes Training and Assistance	0.001	0.003	0.005	0.009	0.012	0.022	0.051	0.075	0.098	0.119
Energy Star: Clothes Washers	0.002	0.003	0.004	0.005	0.006	0.008	0.009	0.010	0.012	0.015
Energy Star: Refrigerators	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.004	0.006
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.001	0.001	0.004	0.009	0.015	0.022	0.030
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Energy Star: CFLs	0.001	0.002	0.005	0.010	0.015	0.026	0.069	0.119	0.146	0.150
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002
Weatherization and Intergovernmental Activities Total	**0.009**	**0.019**	**0.032**	**0.048**	**0.061**	**0.093**	**0.185**	**0.270**	**0.332**	**0.369**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.11. NO_X Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.001**	**0.002**	**0.003**	**0.004**	**0.005**	**0.008**	**0.013**	**0.016**	**0.016**	**0.016**
Weatherization Assistance	0.001	0.002	0.003	0.004	0.005	0.008	0.013	0.016	0.016	0.016
2 State Energy Project	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**	**0.004**	**0.006**	**0.008**	**0.008**	**0.008**
State Energy Project	0.001	0.001	0.002	0.003	0.003	0.004	0.006	0.008	0.008	0.008
3 Gateway Deployment	**0.005**	**0.011**	**0.017**	**0.024**	**0.030**	**0.047**	**0.102**	**0.161**	**0.204**	**0.231**
Rebuild America	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.003	0.003
Energy Efficiency Information Outreach	0.002	0.004	0.006	0.007	0.006	0.006	0.006	0.005	0.005	0.005
Building Codes Training and Assistance	0.001	0.002	0.003	0.005	0.007	0.013	0.034	0.052	0.069	0.084
Energy Star: Clothes Washers	0.002	0.003	0.003	0.004	0.005	0.006	0.007	0.009	0.011	0.013
Energy Star: Refrigerators	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.003	0.004
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.000	0.001	0.002	0.006	0.010	0.014	0.020
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Energy Star: CFLs	0.001	0.002	0.003	0.006	0.009	0.016	0.043	0.078	0.095	0.097
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Weatherization and Intergovernmental Activities Total	**0.007**	**0.014**	**0.022**	**0.031**	**0.039**	**0.059**	**0.121**	**0.184**	**0.227**	**0.255**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.12. CO Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**	**0.003**
Weatherization Assistance	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.003	0.003	0.003
2 State Energy Project	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.001**
State Energy Project	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
3 Gateway Deployment	**0.001**	**0.002**	**0.002**	**0.003**	**0.004**	**0.006**	**0.013**	**0.021**	**0.027**	**0.031**
Rebuild America	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Energy Efficiency Information Outreach	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Building Codes Training and Assistance	0.000	0.000	0.000	0.001	0.001	0.001	0.004	0.007	0.009	0.012
Energy Star: Clothes Washers	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
Energy Star: Refrigerators	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: CFLs	0.000	0.000	0.000	0.001	0.001	0.002	0.005	0.009	0.012	0.012
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Weatherization and Intergovernmental Activities Total	**0.001**	**0.002**	**0.003**	**0.004**	**0.005**	**0.007**	**0.016**	**0.025**	**0.031**	**0.035**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.13. PM Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Weatherization Assistance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 State Energy Project	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
State Energy Project	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Gateway Deployment	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.005**	**0.007**	**0.008**
Rebuild America	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Efficiency Information Outreach	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Building Codes Training and Assistance	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.003
Energy Star: Clothes Washers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Refrigerators	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: CFLs	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.003	0.003
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Weatherization and Intergovernmental Activities Total	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.002**	**0.004**	**0.006**	**0.007**	**0.008**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.14. VOC Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Weatherization Assistance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 State Energy Project	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
State Energy Project	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Gateway Deployment	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**
Rebuild America	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Efficiency Information Outreach	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Building Codes Training and Assistance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Energy Star: Clothes Washers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Refrigerators	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: CFLs	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Weatherization and Intergovernmental Activities Total	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**	**0.004**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.15. Consumer (Energy) Cost Savings (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**$60**	**$117**	**$175**	**$233**	**$292**	**$411**	**$716**	**$917**	**$934**	**$944**
Weatherization Assistance	$60	$117	$175	$233	$292	$411	$716	$917	$934	$944
2 State Energy Project	**$25**	**$48**	**$70**	**$92**	**$114**	**$158**	**$275**	**$352**	**$359**	**$367**
State Energy Project	$25	$48	$70	$92	$114	$158	$275	$352	$359	$367
3 Gateway Deployment	**$259**	**$479**	**$743**	**$963**	**$1,247**	**$2,031**	**$5,013**	**$8,611**	**$11,018**	**$12,601**
Rebuild America	$11	$19	$33	$53	$71	$113	$155	$154	$157	$160
Energy Efficiency Information Outreach	$90	$175	$258	$253	$251	$247	$249	$255	$259	$263
Building Codes Training and Assistance	$31	$73	$124	$183	$257	$509	$1,531	$2,572	$3,461	$4,304
Energy Star: Clothes Washers	$94	$124	$156	$188	$221	$285	$404	$519	$641	$774
Energy Star: Refrigerators	$3	$7	$13	$22	$31	$48	$91	$125	$164	$209
Energy Star: Electric Water Heaters	$1	$4	$8	$17	$36	$107	$299	$531	$804	$1,119
Energy Star: Gas Water Heaters	$0	$0	$1	$3	$5	$10	$27	$69	$113	$162
Energy Star: Room Air Conditioners	$2	$4	$6	$7	$9	$12	$21	$30	$40	$52
Energy Star: CFLs	$26	$70	$137	$230	$359	$688	$2,214	$4,322	$5,331	$5,495
Energy Star: Dishwashers	$1	$3	$5	$6	$8	$12	$22	$34	$48	$63
Weatherization and Intergovernmental Activities Total	**$344**	**$643**	**$988**	**$1,288**	**$1,653**	**$2,600**	**$6,003**	**$9,880**	**$12,311**	**$13,912**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.16. Non-Energy Cost Savings (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**$47**	**$45**	**$45**	**$45**	**$46**	**$46**	**$47**	**$47**	**$47**	**$47**
Weatherization Assistance	$47	$45	$45	$45	$46	$46	$47	$47	$47	$47
2 State Energy Project	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
State Energy Project	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3 Gateway Deployment	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Rebuild America	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Efficiency Information Outreach	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Building Codes Training and Assistance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Clothes Washers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Refrigerators	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Electric Water Heaters	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Gas Water Heaters	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Room Air Conditioners	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: CFLs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Dishwashers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Weatherization and Intergovernmental Activities Total	**$47**	**$45**	**$45**	**$45**	**$46**	**$46**	**$47**	**$47**	**$47**	**$47**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.17. Incremental Private Investment (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**$536**	**$532**	**$539**	**$546**	**$554**	**$569**	**$578**	**$578**	**$578**	**$578**
Weatherization Assistance	$536	$532	$539	$546	$554	$569	$578	$578	$578	$578
2 State Energy Project	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**
State Energy Project	$164	$164	$164	$164	$164	$164	$164	$164	$164	$164
3 Gateway Deployment	**$1,203**	**$1,605**	**$1,837**	**$2,086**	**$2,187**	**$2,790**	**$2,739**	**$2,201**	**$1,261**	**$449**
Rebuild America	$166	$163	$242	$317	$311	$392	$12	$9	$10	$9
Energy Efficiency Information Outreach	$180	$170	$167	$169	$166	$165	$164	$172	$174	$173
Building Codes Training and Assistance	$156	$207	$255	$297	$367	$791	$1,072	$997	$852	$913
Energy Star: Clothes Washers	$290	$336	$341	$345	$345	$351	$422	$443	$465	$488
Energy Star: Refrigerators	$80	$191	$272	$366	$369	$380	$409	$425	$441	$458
Energy Star: Electric Water Heaters	$9	$17	$31	$53	$90	$161	$149	$151	$153	$155
Energy Star: Gas Water Heaters	$0	$10	$17	$26	$37	$50	$103	$111	$120	$129
Energy Star: Room Air Conditioners	$239	$369	$371	$373	$366	$358	$423	$441	$458	$477
Energy Star: CFLs	$23	$29	$30	$29	$24	$26	-$144	-$683	-$1,553	$-2,503
Energy Star: Dishwashers	$59	$111	$110	$110	$111	$117	$128	$135	$142	$149
Weatherization and Intergovernmental Activities Total	**$1,903**	**$2,300**	**$2,539**	**$2,796**	**$2,905**	**$3,524**	**$3,481**	**$2,942**	**$2,003**	**$1,191**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.18. Employment Impacts, Savings Only (Thousand Jobs/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.6**	**0.8**	**1.2**	**1.6**	**2.0**	**2.9**	**5.0**	**6.3**	**6.5**	**6.6**
Weatherization Assistance	0.6	0.8	1.2	1.6	2.0	2.9	5.0	6.3	6.5	6.6
2 State Energy Project	**0.3**	**0.5**	**0.7**	**0.9**	**1.1**	**1.5**	**2.6**	**3.3**	**3.3**	**3.4**
State Energy Project	0.3	0.5	0.7	0.9	1.1	1.5	2.6	3.3	3.3	3.4
3 Gateway Deployment	**3.6**	**4.3**	**6.8**	**8.9**	**11.7**	**19.3**	**48.8**	**84.7**	**108.2**	**123.1**
Rebuild America	0.1	0.2	0.3	0.4	0.6	0.9	1.2	1.2	1.3	1.3
Energy Efficiency Information Outreach	1.3	1.5	2.3	2.2	2.2	2.1	2.2	2.2	2.2	2.3
Building Codes Training and Assistance	0.5	0.7	1.3	1.9	2.6	5.0	14.7	24.7	33.0	40.9
Energy Star: Clothes Washers	1.2	1.0	1.3	1.5	1.8	2.3	3.3	4.2	5.2	6.3
Energy Star: Refrigerators	0.0	0.1	0.1	0.2	0.3	0.5	0.9	1.3	1.7	2.2
Energy Star: Electric Water Heaters	0.0	0.0	0.1	0.2	0.4	1.1	3.1	5.5	8.3	11.5
Energy Star: Gas Water Heaters	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.8
Energy Star: Room Air Conditioners	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5
Energy Star: CFLs	0.4	0.7	1.4	2.4	3.7	7.1	22.8	44.6	55.1	56.8
Energy Star: Dishwashers	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.4	0.5	0.7
Weatherization and Intergovernmental Activities Total	**4.5**	**5.6**	**8.7**	**11.4**	**14.8**	**23.6**	**56.3**	**94.3**	**118.0**	**133.0**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.19. Income Impacts, Savings Only (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**$7**	**$6**	**$7**	**$8**	**$9**	**$11**	**$16**	**$19**	**$19**	**$20**
Weatherization Assistance	$7	$6	$7	$8	$9	$11	$16	$19	$19	$20
2 State Energy Project	**$5**	**$7**	**$11**	**$14**	**$17**	**$23**	**$41**	**$52**	**$53**	**$54**
State Energy Project	$5	$7	$11	$14	$17	$23	$41	$52	$53	$54
3 Gateway Deployment	**$37**	**$54**	**$87**	**$112**	**$145**	**$238**	**$611**	**$1,062**	**$1,353**	**$1,533**
Rebuild America	$1	$1	$2	$4	$5	$8	$11	$11	$12	$12
Energy Efficiency Information Outreach	$16	$23	$34	$33	$32	$32	$32	$32	$33	$33
Building Codes Training and Assistance	$6	$12	$20	$30	$40	$75	$215	$358	$473	$580
Energy Star: Clothes Washers	$9	$7	$9	$11	$12	$16	$23	$28	$34	$41
Energy Star: Refrigerators	$0	$1	$2	$3	$4	$6	$11	$16	$20	$26
Energy Star: Electric Water Heaters	$0	$0	$1	$2	$4	$13	$37	$66	$100	$140
Energy Star: Gas Water Heaters	$0	$0	$0	$0	$0	-$1	-$2	-$4	-$7	$-9
Energy Star: Room Air Conditioners	$0	$0	$1	$1	$1	$2	$3	$4	$5	$6
Energy Star: CFLs	$4	$9	$17	$29	$45	$86	$278	$546	$675	$696
Energy Star: Dishwashers	$0	$0	$1	$1	$1	$1	$3	$4	$6	$8
Weatherization and Intergovernmental Activities Total	**$49**	**$68**	**$105**	**$134**	**$171**	**$272**	**$667**	**$1,133**	**$1,425**	**$1,607**

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B.3 Weatherization Assistance Project

Weatherization Assistance Project Decision Unit

Project Objective:[1]

The Weatherization Assistance Project provides cost-effective energy-efficiency services to low-income constituencies who otherwise could not afford the investment but who would benefit significantly from the cost savings of energy-efficiency technologies. The project focuses on households that spend a disproportionate amount of their income for energy, giving priority to households with elderly members, persons with disabilities, and children.

In 1999 the Weatherization network of state and local agencies adopted a new strategic vision called Weatherization *Plus.* The new strategy emphasizes a shift to the whole-house approach and includes electric baseload measures and advanced technologies. Within the new $2500 legislative cap on average expenditure per household, the mix of measures include those with enhanced impacts on greenhouse gas emissions and pollution reduction. Such measures include intensified building envelope and heating/cooling system measures, more health and safety measures (supporting other community goals), and more baseload uses such as water heating and lighting.

Long-Term Goal:[1]

The long-term goal of the Weatherization Assistance project is to achieve average energy savings of 31 million Btu in an additional 2.3 million existing low-income homes through 2011, consistent with the President's plan to increase Weatherization funding by $1.4 billion over FY 2000 baselines for the 10-year period. This investment will save participating households an estimated $4.2 billion in reduced energy bills over the period.

Market Segment:

Target Market

- **Market Description:** The market includes low-income homes and target measures include air sealing; caulking and weather stripping; furnace and boiler tuneup, repair, and replacement;

Weatherization Assistance Project

Project Type:
Envelope/Grant

Target Market:
Low-income residential housing in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Energy savings per housing unit

Modeling Tool:
Spreadsheet

Project Manager:
Greg Reamy

Website:
http://www.eren.doe.gov/buildings/weatherization_assistance/

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FY2004 Benefits [c]

Primary Energy Savings (TBtu)

2004	2005	2010	2020
8.6	16.9	57.6	122.5

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.143	0.282	0.977	2.040

Consumer Cost Savings (million $)

2004	2005	2010	2020
60	117	411	917

[c] Benefits estimates for the Weatherization Assistance Project are the result of both DOE funding and an additional $300 million per year in leverage funds.

B.3 Weatherization Assistance Project

Weatherization Assistance Project Decision Unit

cooling system tuneup and repair; replacement of windows and doors; addition of storm windows and doors; insulation of building shells; and replacement of air conditioners, whole-house fans, evaporative coolers, screening, and window films.[2] Weatherization *Plus* expands this strategy to include water heating, refrigeration, lighting, and cooling.[1]

- **Size of Market:** ~29 million eligible low-income homes are included in the market.

Methodology:

For the GPRA metrics, this project was characterized based on an estimated level of savings per household, cost to weatherize each household, budget request, leveraged funds, and an assumed life expectancy of 15 years for weatherization measures. The basic assumptions were derived from a spreadsheet provided by the Weatherization project in September 2001.

Estimated Savings Per Household

Table B-3.1 shows the savings per household used for each region for the FY 2004 metrics.

Table B-3.1. Savings Per Household for the Weatherization Assistance Project

Region	Regular Household Savings (MMBtu/yr)	*Plus* Household Savings (MMBtu/yr)
South	22.25	24.23
Northeast	31.20	46.04
West	19.04	20.31
Midwest	31.20	49.21

The figures in the table were calculated based on the 1997 ORNL meta-evaluation report,[2] the ORNL *Meeting the Challenge* report,[3] and special tabulations from the 1997 "Residential Energy Consumption Survey."[4] Previous year's estimates were based on project resource allocations at levels reflecting a formula bias towards homes in colder climates in the Northeast and Midwest. The higher budget levels projected for FY 2002 and beyond are allocated under a formula that shifts a higher proportion of new revenues to the South and West, where saving rates are lower.

Of the units weatherized in FY 2004, ~40% were assumed by the Weatherization Project[3] to have the higher savings rates associated with Weatherization *Plus*. In the *Meeting The Challenge* report,[3] these savings rates were calculated on a regional basis and multiplied times the expected number of *Plus* households in each region.

To develop energy savings by building type, PNNL evaluated historical Weatherization project data in the 1997 ORNL report[2] concerning the types of households weatherized (see Table B-3.2).

B.3 Weatherization Assistance Project

Weatherization Assistance Project Decision Unit

Table B-3.2. Percent of Weatherized Households by Type

Household Type	% of Weatherized Households
Single Family	64.0%
Mobile Home	20.0%
Multi Family	16.0%

To develop energy savings by fuel type, PNNL also drew upon the historical primary fuel Weatherization project data in the 1997 ORNL report[2]. Because the GPRA metrics are reported for electricity, natural gas, and fuel oil, but not for LPG and kerosene, other fuels were allocated within those types based on similarities of emissions. Table B-3.3 shows the allocation approaches used.

Table B-3.3. Percent of Weatherized Households by Fuel Type

Primary Heating Fuel	% of Weatherized Households	Categorized As
Natural Gas	50.6	Natural Gas
Liquid Propane Gas	13.2	
Fuel Oil	16.0	Fuel Oil
Kerosene	3.2	
Other (includes wood and coal)	7.5	
Electricity	9.5	Electricity

Cost to Weatherize Each Household

PNNL employed the average household weatherization cost of $1,775; this estimate does not include training, technical assistance and administrative costs. Incremental investment beyond this for Weatherization *Plus* homes, estimated at an average of $1,400 by the Weatherization project, was assumed to be provided by other organizations, that is by leveraged funds. Table B-3.4 shows the estimated total costs by region for *Plus* homes.

Table B-3.4. Estimated Regional Costs for Weatherization *Plus* Homes

Region	Cost per *Plus* Household
South	$2861
Northeast	$3674
West	$1814
Midwest	$3429

B.3 Weatherization Assistance Project

Weatherization Assistance Project Decision Unit

DOE Funds Available

Because this is a grant project, this activity was assumed not to occur without DOE funding; therefore, we did not apply the NRC (acceleration-to-market) methodology. The FY 2004 Weatherization planning budget and forecast for FY 2004 to FY 2030 was used to calculate the number of households weatherized. The total funds allocated to training and technical assistance and administrative costs were estimated to total 20% during the period.

Leveraged Funding

Leveraging means that the project efforts are augmented by contributions from organizations other than DOE. These contributions can take the form of direct project-targeted funding or in-kind contributions such as staff, research-in-kind, facilities, or other nonmonetary resources. In any case, this definition only includes resources that can clearly be attributed to project activities and that are used to augment those activities.

Funding for activities conducted under the Weatherization Assistance project is leveraged; beyond DOE, funding sources include the Low-Income Home Energy Assistance Program at the U.S. Department of Health and Human Services, energy utilities, state agencies, private companies, and Petroleum Violation Escrow funds.

Rationale for Benefits Attribution to DOE

A series of arguments support the overall proposition that the entire benefits of the Weatherization Assistance project should accrue to DOE. These arguments take three basic forms. First, some funding is earmarked, or directed to, DOE's Weatherization Project from other projects and programs. As such, it is almost an artificial construct that the dollars happen to originate elsewhere because fulfilling the fundamental mission is planned, managed, and executed by the Weatherization Project.

Second, DOE's Weatherization project forms the foundation on which all other activities are built. That is, the DOE Weatherization project funds the development and upkeep of the basic core capabilities on which other agencies and organizations draw. If the Weatherization project at DOE did not exist, weatherization activities by States and other agencies would first have to replace these foundational capabilities, which would diminish the benefits from those projects substantially.

Third, the Weatherization project provides key management functions for activities funded by outside organizations. That is, the project provides planning, execution, and evaluation assistance thereby reducing overhead costs for these organizations. As such, more money and assistance are allowed to flow directly to implement project efforts.

Remaining Issues

In discussing the issue of crediting benefits to DOE resulting from leveraged funds, two problems should be noted. First, leveraged funding is being included in estimating those benefits. Comparative measures, such as Btu saved per dollar of project expenditure, should consider these leveraged funds.

B.3 Weatherization Assistance Project

Weatherization Assistance Project Decision Unit

Second, project assumptions about what weatherization means, in practice, may not always apply to weatherizations performed with leveraged funds, making the actual field savings estimates more speculative. Currently, the Weatherization Assistance benefits (energy savings) estimates are derived based on certain assumptions about the types of activities being funded and the outputs of those activities. For example, within the project, DOE sets rules on the types of actions (e.g., insulating the attic to a certain R-Value) that are taken when weatherizing a home. From this, the energy savings associated with these actions can be estimated. If a different set of rules applies to the leveraged funds and consequently the leveraged funds pay for actions that result in significantly different outputs, the estimation procedure may no longer adequately characterize the project and the savings might be quite different. At this time, no method is in place to capture the potential differences.

Leveraged Funding Assumptions

For FY 2004, leveraged funding of almost $300 million per year was assumed, based on Weatherization Project projections. A 20% project overhead was subtracted from the total before calculating the number of households weatherized with these funds. Leveraged funding for the *Plus* homes was estimated to total $68.7 million in FY 2004, based on the costs reflected in ORNL's *Meeting The Challenge* report.[3] Based on Weatherization Project projections, PNNL assumed the remainder of the leveraged funds would be used on regular and *Plus* homes in a 60/40 ratio.

Spreadsheet Model Details

The DOE budget and leveraged funding forecasts outlined above were used to determine the number of households weatherized in each category (regular or *Plus*) for each of the four regions (South, Northeast, West, and Midwest) based on the weatherization costs per household and assumptions regarding the use of leveraged funds. Table B-3.5 shows the projection for regular and *Plus* households to be weatherized. The number of households weatherized for each category was assumed to be constant from 2011 through 2030.

Table B-3.5. Projected Regular and *Plus* Households to be Weatherized

	2004	2005	2006	2007	2008	2009	2010	2011
Total Households	231,660	222,395	224,096	225,830	227,599	229,403	231,243	233,119
Regular South	26,441	22,703	22,888	23,076	23,267	23,463	23,663	23,867
Regular Northeast	31,710	26,778	27,006	27,239	27,476	27,717	27,963	28,213
Regular West	28,905	27,177	27,321	27,466	27,615	27,766	27,920	28,077
Regular Midwest	41,434	34,538	34,833	35,134	35,441	35,755	36,076	36,403
Plus South	20,812	22,703	22,888	23,076	23,267	23,463	23,663	23,867
Plus Northeast	25,370	26,778	27.006	27,239	27,476	27,717	27,963	28,213
Plus West	25,280	27,177	27,321	27,466	27,615	27,766	27,920	28,077
Plus Midwest	31,707	34,538	34,833	35,134	35,441	35,755	36,076	36,403

The number of households in each category was multiplied by the estimated savings level for each category (as shown in Table B-3.1). The estimated savings level for each household

B.3 Weatherization Assistance Project

Weatherization Assistance Project Decision Unit

category was further divided by household type and then by fuel type, based on the Tables B-3.2 and B-3.3. Savings from each household weatherized were assumed to be in effect for 15 years; i.e., savings from households weatherized in 2004 were included in the annual total savings estimates for the years 2004 through 2018.

Project/Technology Consumer Costs:

Because the Weatherization Assistance project is a grant-type project, the recipients of the improvements do not bear the actual investment costs – these costs are paid for with the DOE and leveraged funds. For purposes of modeling the employment and income impacts stemming from the Weatherization Assistance project, an average cost per household weatherized was used to calculate the national employment and income impacts.

Non-Energy Benefits:

A net present value of $161 per household[5] (1989 $), adjusted for inflation, was used for the FY 2004 effort, based on the estimated non-energy benefits resulting from enhanced property values and extended lifetimes of the dwellings, reduced fires, and reduced arrearages. Non-energy benefits associated with employment and environmental externalities are captured elsewhere in this report and therefore are not included in the calculation of non-energy benefits.

Sources:

(1) *FY 2002 Budget Request – Data Bucket Report for Weatherization Assistance Program* (internal BT document).

(2) Berry, L.G., M.A. Brown, and L.F. Kinney. 1997. *Progress Report of the National Weatherization Assistance Program*, ORNL/CON-450, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(3) Schweitzer, M. and J.F. Eisenberg. 2000. *Meeting The Challenge: The Prospect of Achieving 30 Percent Energy Savings Through the Weatherization Assistance Program*. ORNL/CON 479, Draft Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(4) Eisenberg, J.F., Oak Ridge National Laboratory. 2001. Special tabulations for the Weatherization Population derived from the 1997 Residential Energy Consumption Survey.

(5) Brown, M.A., L.G. Bery, R.A. Balzer, and E. Faby. 1993. *National Impacts of the Weatherization Assistance Program in Single-Family and Small Multifamily Dwellings*. ORNL/CON-326, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

B.4 State Energy Project

State Energy Project Decision Unit

Project Objective:[1]

The State Energy Project (SEP) provides a supportive framework with sufficient flexibility to enable states to address their energy priorities in concert with national priorities. It supports the federal/state partnerships that are crucial to developing energy policies and deploying energy technologies. SEP emphasizes outreach, technology deployment, and partnerships to accomplish energy-efficiency and renewable energy projects at the state and local level.

Long-Term Goal:[1]

SEP's strategic plan for the 21st century establishes three key goals to be accomplished for 2010: 1) maximize energy, environmental, and economic benefits through increased collaboration at the federal, state, and community level; 2) increase market acceptance of energy-efficiency and renewable energy technologies, practices, and products; and 3) use innovative approaches to reach market segments and meet policy goals not typically addressed by market-based solutions.

Market Segment:

Target Market

- Market Description: The markets include all markets (including buildings, transportation, industry, and power technologies) except new construction and all categories of energy end use.

Methodology:

For the GPRA metrics, the State Energy project project is characterized based on an estimated level of savings per budget dollar, budget request, and leveraged funds. PNNL derived the basic assumptions from a spreadsheet the project provided in FY 1999. We revised the assumptions slightly because of an external peer review conducted by A.D. Little for the FY 2002 GPRA effort.

State Energy Project

Project Type:
Grant

Target Market:
All sectors in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Energy savings per project dollar

Modeling Tool:
Spreadsheet

Project Manager:
Faith Lambert

Website:
http://www.eren.doe.gov/buildings/state_energy/

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FY 2004 Benefits [d]
Primary Energy Savings (TBtu)

2004	2005	2010	2020
4.0	7.8	24.7	48.7

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.073	0.147	0.490	0.933

Consumer Cost Savings (million $)

2004	2005	2010	2020
25	48	158	352

[d] Benefits estimates for the State Energy Project are the result of both DOE funding and an additional $155 million per year in leverage funds.

B.4 State Energy Project

State Energy Project Decision Unit

Estimated Savings Per Project Dollar

For FY 2004, the estimated savings per project dollar were based on historical information on project dollars from SEP and estimated savings from projects for 1987 through 1993. The SEP provided the original figures. Based on concerns about the historical versus future project mix, as raised in the FY 2002 GPRA effort peer review, savings based on recycling and wood and biomass renewables were removed from the mix. Table B-4.1 presents the resulting energy savings estimates and project dollars by sector.

Table B-4.1. SEP Energy Savings Estimates and Project Dollars

Sector	Total Project Dollars (1987 – 1993)	Non-Electric End-Use Savings (MMBtu/yr)	Electric End-Use Savings (MMBtu/yr)
Residential Buildings	172,142,693	201,405	50,351
Commercial Buildings	369,046,708	283,728	419,316
Industry	78,283,071	249,985	182,408
Transportation	290,320,750	145,297	0
Utilities	21,621,306	58,163	3,859
Education	77,650,746	74,329	40,023
Miscellaneous	87,135,236	0	0
Totals	*1,096,200,511*	*1,012,906*	*695,957*

The end-use savings for each sector in Table B-4.1 were divided by the annual average dollars spent on the project (equal to total project dollars divided by seven years) to yield the average MMBtu savings per project dollar of 0.0044 MMBtu electric and 0.0065 non-electric end-use energy savings, as Table B-4.2 shows.

Table B-4.2. SEP Electric and Non-Electric Savings (MMBtu/project $)

Sector	Total End Use	Electric	Non-Electric
Residential Buildings	0.0102	0.0020	0.0082
Commercial Buildings	0.0133	0.0080	0.0054
Industry	0.0387	0.0163	0.0224
Transportation	0.0035	0.0000	0.0035
Utilities	0.0201	0.0012	0.0188
Education	0.0103	0.0036	0.0067
Miscellaneous	0.0000	0.0000	0.0000
Overall	*0.0109*	*0.0044*	*0.0065*

To develop energy savings by fuel type for other fuel savings, PNNL drew upon historical information to estimate savings of natural gas (20%) and fuel oil (80%). The savings also were split between the residential and commercial sectors (with the commercial sector

B.4 State Energy Project

State Energy Project Decision Unit

representing savings from industrial, transportation, and utilities) based on the historical split of savings (7% residential and 93% nonresidential).

DOE Funds Available

Because this is a grant project, this activity was assumed not to occur without DOE funding; therefore, we did not apply the NRC (acceleration-to-market) methodology. The FY 2004 planning budget and forecast for FY 2004 to FY 2030 was used to calculate the estimated savings.

Leveraged Funding

Leveraging means that the project efforts are augmented by contributions from organizations other than DOE. These contributions can take the form of direct project-targeted funding or in-kind contributions like staff, research-in-kind, facilities, or other non-monetary resources. In any case, this definition only includes resources that can clearly be attributed to project activities and that are used to augment those activities.

Activities conducted under the banner of the SEP are not only funded by the federal government, through DOE, but also through state matching funds, income generated by SEP activities, and Petroleum Violation Escrow funds.

Rationale for Benefits Attribution

A series of arguments support the overall proposition that the entire benefits of the Weatherization Assistance project should accrue to DOE. These arguments take three basic forms. First, some funding is earmarked or directed to DOE's SEP from other projects and programs. As such, it is almost an artificial construct that the dollars happen to originate elsewhere because fulfilling the fundamental mission is planned, managed, and executed by SEP.

Second, the SEP at DOE forms the foundation on which all other activities are built. That is, the DOE SEP funds the development and upkeep of the basic, core capabilities on which other agencies and organizations draw. If the SEP at DOE did not exist, SEP efforts by States and other agencies would first have to replace these foundational capabilities, which would diminish the benefits from those projects substantially.

Third, the SEP provides key management functions for activities funded by outside organizations; i.e., the project provides planning, execution, and evaluation assistance thereby reducing overhead costs for these organizations. As such, more money and assistance are allowed to flow directly to implement of project efforts.

Remaining Issues

Two problems are related to crediting benefits to DOE resulting from leveraged funds. First, leveraged funding is being included in estimating those benefits. Comparative measures, such as Btu saved per dollar of project expenditure, should consider these leveraged funds.

B.4 State Energy Project

State Energy Project Decision Unit

Second, measurement problems may make savings estimates related to the leveraged funds more speculative. Currently, the benefits (energy savings) estimates are derived based on certain assumptions about the types of activities being funded and the outputs of those activities. If a different set of rules apply to the leveraged funds and consequently the leveraged funds pay for actions that result in significantly different outputs, then the estimation procedure may no longer adequately characterize the project and the savings might be quite different. At this time, no method is in place to capture the potential differences.

Leveraged Funding Assumptions

For FY 2004, funds were assumed to be leveraged at a ratio of $4 for every budget dollar.

Spreadsheet Model Details

To calculate SEP energy savings, the savings estimates of 0.0044 MMBtu electric and 0.0065 non-electric end-use energy savings were applied to the total of the SEP budget and leveraged funding forecasts for each year in the analysis period. These savings were further split by applying the estimated fuel splits and building sector splits, as outlined in the section above, "Estimated Savings per Project Dollar." Savings from each year were assumed to be in effect for 15 years, i.e., savings from 2004 were included in the annual total savings estimates for the years 2004 through 2018.

Project/Technology Consumer Costs:

Because the State Energy Project is a grant-type project, the recipients of the improvements do not bear the actual investment costs – these costs are paid for with the DOE and leveraged funds. For purposes of modeling the employment and income impacts stemming from the State Energy Project, an average cost per grant was used to calculate the national employment and income impacts.

Non-Energy Benefits:

- Cleaner air and water
- Increased jobs
- Enhanced national security
- Increased economic competitiveness in world markets
- Mitigation of global warming.[1]

Source:

(1) *FY 2002 Budget Request – Data Bucket Report for State Formula Grants Program.*

B.5 Rebuild America

Gateway Deployment Decision Unit

Project Objective:[1]

The Rebuild America project builds collaborative partnerships with states and communities to help them develop and implement environmentally and economically sound activities through smarter energy use. Rebuild America connects people, resources, proven ideas, and innovative practices to solve problems. The project provides one-stop shopping for information and assistance on how to plan, finance, implement, and manage retrofit projects to improve buildings energy efficiency and helps communities find other resources on renewable energy applications, efficient new building designs, energy education, and other innovative energy conservation measures.

Rebuild America supports the public/private Energy Smart Schools initiative and competitive Community Energy Grants to support community-wide energy projects.

Long-Term Goal:[3]

The project's long-term goals include saving energy by committing 2.8 billion ft^2 to retrofit by 2010.

Market Segment:

Performance Objective: [3]

- **Displaced Technology:** The project displaces current design/building practices.
- **Performance Target:** The target is to reduce heating, cooling and water heat energy use in retrofitted and new buildings by 25%/ft^2 in 2004 and 40%/ft^2 by 2010.

Target Market

- **Market Description:** Rebuild America helps designated communities design and implement energy-saving projects that respond to their own circumstances and goals, providing access to a portfolio of technical assistance, with a core focus on existing commercial and institutional buildings. The general target market includes new and existing multifamily housing, public/assisted single-family residential units, and commercial buildings, particularly new and existing assembly, health care, lodging, office, and education buildings.

Rebuild America

Project Type:
Whole Building

Target Market:
Existing commercial buildings, multifamily units and residential housing receiving public assistance in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
% change in load

Modeling Tool:
BESET

Project Manager:
Daniel Sze

Website:
http://www.eren.doe.gov/buildings/rebuild/

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FY 2004 Benefits
Primary Energy Savings (TBtu)

2004	2005	2010	2020
1.6	3.0	16.7	20.8

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.027	0.051	0.292	0.354

Consumer Cost Savings (million $)

2004	2005	2010	2020
11	19	113	154

B.5 Rebuild America

Gateway Deployment Decision Unit

- **Market Size:**[2] The primary market is the commercial building sector, which includes ~68.7 billion square feet of building space; however, the five commercial building types that this project targets make up a total of ~36 billion square feet. The public assistance[1] and multifamily housing that this project also targets make up an additional 27 billion square feet.
- **Penetration Goal:** This activity was assumed not to occur without DOE funding; therefore, the NRC methodology (acceleration-to-market) was not applied. The penetration rates shown in Table B-5.1 are based on project goals of committing 2.8 billion square feet by 2010.

Table B-5.1. Penetration Goals for Rebuild America

Building Type*	Penetration Rates (%)		
	2004	2010	2020
Targeted Commercial Buildings	0.20	2.20	2.60
Multifamily	0.20	2.20	2.60
Single Family	0.01	0.07	0.08
* For all building types, the building vintage is both new and existing and includes both north and south regions.			

Methodology:

Of the 250 million ft^2 added to the project each year, not all of the square footage per partner is retrofitted in one year. The building retrofits (and actual savings) are assumed to occur evenly over four years. Penetration rates were calculated using the square footage affected by the project as a percentage of the total square footage in the existing building stock.

PNNL applied the load reductions specified in the performance objective to the baseline end-use loads to determine energy savings at the building level. These building-level energy savings were translated into national energy savings using the penetration rates and building stock within the target market and then were adjusted using the most recent budget request information.

Project/Technology Consumer Costs:

- **Cost of Conventional Technology:**[4] Average of \$81/ft^2 for new commercial and multifamily; \$0 for existing buildings.
- **Cost of WIP Technology:**[1] \$82.60/ft^2 for new commercial and multifamily; \$3/ft^2 (2001 to 2009), increasing to \$4/ft^2 (2010 to 2030) for existing buildings.
- **Incremental Cost:** 2% above base for new buildings; \$3/ft^2 (2001 to 2009), increasing to \$4/ft^2 (2010 to 2030) for existing buildings.

B.5 Rebuild America

Gateway Deployment Decision Unit

Non-Energy Benefits:[1]

- Revitalized neighborhoods and business districts
- Improving school facilities
- Better low-income housing
- Positive economic impact from keeping dollars locally and increasing property values.

Sources:

(1) *FY 2002 Budget Request – Data Bucket Report for Rebuild America Program* (includes Energy Smart Schools and Competitively Selected Community Program) (internal BT document).
(2) Commercial building and multifamily square footage numbers come from AEO 2002.
(3) FY 2003 Data Collection interview with the project manager, Daniel Sze, August 20, 2001.
(4) RS Means Company, Inc. 2000. *"RS MEANS Square Foot Costs"*. 22nd Edition, Kingston, MA.

B.6 Information Outreach

Gateway Deployment Decision Unit

Project Objective:[1]

The Information Outreach project provides the technical assistance needed to conduct the various planned activities that will educate target audiences. Specifically, the project conceptualizes, plans, and implements a systematic approach to the marketing and communication objectives and evaluation of the projects it supports.

Long-Term Goal:[1]

By 2010, the project goal is to support long-term success in developing energy-efficient systems and processes and to improve the technology transfer/information exchange process.

Market Segment:

Target Market

- Market Description: The market includes new residential and existing commercial buildings in all climate zones.

Methodology:[2]

A slightly modified version of an evaluation conducted for the Information Outreach project was used to estimate this project's GPRA benefits. This section draws extensively from the report[2] of that evaluation, which follows protocols used by major public relations firms and prominent measurement organizations. The major aspects of the evaluation protocols are as follows:

- Preparation (EERE activities)
  - Adequacy of background information base for designing the project
  - Appropriateness of the message and activity
  - Quality of the message and activity presentations.
- Implementation (distribution effectiveness)
  - Number of messages sent to the media and activities designed
  - Number of activities placed and implemented
  - Number of individuals who receive messages and activities
  - Number of individuals who are responsible for messages and activities.
- Impact (action taken)
  - Number of individuals who learn message content
  - Number of individuals who change opinions
  - Number of individuals who change attitudes

Information Outreach

Project Type:
Information/Education

Target Market:
New residential and existing commercial in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Energy savings per budget dollar

Modeling Tool:
Spreadsheet

Project Manager:
Lani McRae

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FY 2004 Benefits
Primary Energy Savings (TBtu)

2004	2005	2010	2020
14.6	29.0	39.2	36.0

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.249	0.507	0.722	0.636

Consumer Cost Savings (million $)

2004	2005	2010	2020
90	175	247	255

B.6 Information Outreach

Gateway Deployment Decision Unit

- Number of individuals who behave as desired
- Number of individuals who repeat behavior
- Social and cultural change.

The methodology is summarized as follows (details are contained in Messersmith & Azim 2000):

1. Choose measurable target audiences from the EERE strategic plan (e.g., homeowners, commercial builders, and building retrofit decision-makers) who can implement an EERE strategy, tip, or technology.
2. Determine the energy-savings potential of each representative in the target group from the *BTS Core Data Book*,[3] EERE programmatic experience, and the EIA.
3. Count the total number of impressions from each distribution method and determine how many resulted from commercial builders, building retrofit decision-makers, and individual homeowners (target group) (see Table B-6.1).
4. Use industry-accepted norms to determine what percentage of the target audience who received the message are likely to change their opinion or behavior.
5. Multiply the results in step 4 for each distribution mechanism by the Btu savings potential calculated for each target audience member in step 2.

Table B-6.1. Number of Instances an EERE Key Message was Seen or Heard

Deployment	FY 2000	FY 1999	FY 1998	Cumulative Impact
Conferences (attendees)	46,300	66,650	1,000	113,950
Internet (page views)	1 million	2.4 million	756,426	4.3 million
Media (circulation)	763 million	942 million	1.6 trillion	3.3 trillion
Direct Mail (recipients)	35,812	120,064	30,300	186,176
EREC* (recipients)	17,783	58,984	68,294	145,061
Training (handouts)	0	3,500	872	4,372
Hotline (calls)	0	800	1,623	2,423
Totals	764 million	944 million	1.6 trillion	3.3 trillion
* Energy Efficiency and Renewable Energy Clearinghouse.				

The evaluation prepared for the project by Technologists, Inc. (Messersmith & Azim 2000) estimated total delivered energy savings over a 2½-year period of 34.8 TBtu, resulting in an annual energy savings of 13.92 TBtu. The evaluation assumed that savings lasted for 3 years, after which they are supplanted by activities the decisionmaker would have undertaken in any event. As a result, savings increase over three years to 41.76 TBtu (13.92 x 3) and then stay constant. In the evaluation,[2] the savings are assumed to be 5% residential and 95% commercial, based on the types of decisionmakers the project reaches. The fuel distribution of the savings was assumed to match that of the rest of the BT/WIP portfolio.

Because the budget request for FY04 was significantly less than that for FY03, the savings estimates were budget-adjusted, as described in Section 1.0 of this document.

B.6 Information Outreach

Gateway Deployment Decision Unit

Project/Technology Consumer Costs (PNNL estimate):

Incremental investment costs were developed assuming a 2-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $2.00).

Non-Energy Benefits:[1]

The challenges of organizing information and communicating effectively are increased by the emergence of new ideas and technologies, the diversity of stakeholders, as well as changing stakeholder needs, assumptions, and perceptions.

Sources:

(1) FY 2002 Budget Request – *Data Bucket Report for Information Outreach Program* (internal BT document).
(2) Messersmith, J., and S.A. Azim. August 2000. *Communication Effectiveness Analysis for GPRA*, Technologists, Inc.
(3) *BTS Core Data Book*. 1999, BT internal document.

B.7 Training and Assistance for Codes

Gateway Deployment Decision Unit

Project Objective:

The objective of this activity is to improve the minimum energy efficiency of new buildings and additions and renovations to buildings requiring code permits. The overarching project, Building Energy Codes, provides technical and financial assistance to states to support their adoption or updating and implementation of regularly upgraded model building energy efficiency codes by state and local jurisdictions. (See the Commercial and Residential Building Integration decision unit characterizations in Appendix A of this document). The project also provides technical assistance to federal agencies to adopt and implement upgraded federal building energy codes.

Long-Term Goal: [1]

The project's long-term goal is to improve the minimum energy efficiency of new commercial and multifamily high-rise buildings by 30% to 35% and new low-rise residential buildings by 10%. (See the Commercial and Residential Building Integration decision unit characterizations in Appendix A.)

Market Segment:

The Commercial and Residential Building Integration decision unit characterizations in Appendix A of this document describe the market segment. The project's impact is achieved through a continuum of the three decision units funded separately.

Methodology:

The Commercial and Residential Building Integration decision unit characterizations describe the methodology. For information on this project, see the documentation for Commercial Building Codes and Residential Building Codes projects in Appendix A.

Sources:

(1) FY 2002 Budget – *Data Bucket Report for Residential Buildings Integration R&D Program* (internal BT document).

Training and Assistance for Codes

Project Type:
Information/Education

Target Market:
New residential and commercial buildings and additions and major renovations in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Savings as the percentage of compliance improvement

Modeling Tool:
Spreadsheet

Project Manager:
Jean Boulin

Website:
http://www.energycodes.gov

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
4.7	23.0	72.0	320.7

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.084	0.207	1.445	6.014

Consumer Cost Savings (million $):

2004	2005	2010	2020
31	73	509	2572

B.8 Energy Star

Gateway Deployment Decision Unit

Project Objective:[1]

The ENERGY STAR project increases the market penetration of high-efficiency appliances, windows, and lighting technologies through consumer education and voluntary industry partnerships. ENERGY STAR works with manufacturers, national and regional retailers, state and local governments, and more than 100 utilities that serve about half of U.S. households. These partners help the government establish energy efficiency criteria, label products, and promote the manufacture and use of ENERGY STAR products[e].

Long-Term Goal:[1]

The project's long-term goal is to achieve a sustained installed base of high-efficiency appliances of 20% by 2010.

Market Segment:

Performance Objective:

- **Displaced Technology:** The project displaces conventional equipment, appliances, and lights.
- **Performance Target:** Performance targets vary by equipment type and size. The following represents a sample of typical ENERGY STAR technologies on the market:
  - Clothes washers – Modified energy factor of 1.26 or greater.
  - Refrigerators – Must exceed the July 1, 2001, minimum federal standards by at least 10%, modeled in NEMS-PNNL as a refrigerator consuming 430 kWh/yr.
  - Electric water heaters – Energy factor ranges from 0.95 to 0.96, modeled in NEMS-PNNL as 0.96.
  - Gas water heaters – Energy factor of 0.60 to 0.65, modeled in NEMS-PNNL as 0.64.
  - Room air conditioners – Must exceed the October 1, 2000, federal standards by at least 10%; the actual energy efficiency ratio depends on the size of the unit.
  - CFLs – Minimum efficacy of 51.3 lumen/watt.
  - Dishwashers – Energy factor of 0.65 or

Energy Star

Project Type:
Market transformation

Target Market:
Commercial sector and residential households with >$45K/yr incomes in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Load/efficiency per affected unit

Modeling Tool:
NEMS-PNNL (appliances, air conditioning, and water heating)
BESET (CFLs)

Project Manager:
Richard Karney

Website:
http://www.energystar.gov

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
18.2	30.5	143.8	598.0

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.311	0.541	2.846	11.463

Consumer Cost Savings (million $):

2004	2005	2010	2020
127	212	1162	5630

[e] http://www.eere.energy.gov/buildings/energystar.html

B.8 Energy Star

Gateway Deployment Decision Unit

greater; typically uses 400 to 450 kWh/year.

Target Market

- **Market Description:** The market is determined by the project equipment. For FY 2004, the following equipment is characterized (residential):
  - Clothes washers
  - Refrigerators
  - Electric water heaters
  - Gas water heaters
  - Room air conditioners
  - CFLs
  - Dishwashers.

Methodology

PNNL modeled clothes washers, refrigerators, electric water heaters, gas water heaters, room air conditioners, and dishwashers in NEMS-PNNL using input from EIA's *Annual Energy Outlook 2001,*[(2)] based on a project goal of ENERGY STAR appliances achieving 20% of the market share by 2010. We modeled ENERGY STAR CFLs in BESET and assumed they would capture 10.5% of incandescent sales in the residential sectors by 2020 (based on goal of capturing 20% of the installed base). It is assumed that ENERGY STAR CFLs will penetrate the high usage residential fixtures where most of the energy is consumed; 76.4% of the energy consumed by residential incandescent lighting is consumed in 28.3% of the sockets[f]. Thus a 20% installed base will impact up to 54% (20%/28.3%*76.4%) of the consumption. However, because it is highly unlikely that the CFLs will actually take all the high utilization sockets and none of the lower utilization sockets, the impact was assumed to be only 37%. This activity was assumed not to occur without DOE funding; therefore, the NRC (acceleration-to-market) methodology was not applied.

Energy Star Technologies Modeled in NEMS-PNNL

Market transformation projects, such as ENERGY STAR, attempt to accelerate market penetration of existing high-efficiency technologies. From a modeling standpoint, these efforts translate into reducing the consumer's discount rate for these energy-efficient technologies. The discount rate for a technology significantly impacts how a consumer determines the present value of the benefits and costs associated with this technology. For ENERGY STAR technologies, most of the costs are incurred at the time the technology is purchased, while most of the energy-saving benefits occur in the future over time. If the discount rate for a given technology is particularly high, the value a consumer places on these future energy-saving benefits will be low relative to the weight the consumer places on present costs. Therefore, to facilitate project modeling , one goal of the ENERGY STAR project is to reduce these discount rates by providing additional information about the potential benefits to the consumer.

[f] http://enduse.lbl.gov/Info/LBNL-39102.pdf . Calculated from data in Table 2.7.

B.8 Energy Star

Gateway Deployment Decision Unit

Within NEMS-PNNL, the two modeling parameters determining the discount rate are labeled Beta1 and Beta2. Beta1 is used as multiplicative factor with the initial cost of the appliance, and Beta2 is used to multiply the annual energy cost. The sum of the two products (i.e., Beta1 * initial cost + Beta2 * operating cost) is used in the logit specification to yield market shares for each technology. As a rough approximation, the ratio of Beta1/Beta2 can be interpreted as the consumer discount rate for a specific technology. In the residential NEMS-PNNL module, the Beta1 and Beta2 coefficients vary among technologies, as do the resulting discount rates. For example, the implied discount rate for refrigerators is 16%, while the discount rate is estimated to be >80% for electric water heaters.
The modifications to the NEMS input file (RTEKTY) required to estimate energy savings in NEMS-PNNL for each technology in an ENERGY STAR project are described in the following sections. The assumed reduction in the discount rate (from ENERGY STAR support) is modeled by reducing the Beta 1 parameter. The baseline assumptions made by the EIA, the changes in the Beta1 coefficients, and the resulting changes in the market shares for the most energy-efficient products are documented by technology.

Modeling the Market for Energy Star Clothes Washers

Technology Choices Available in the Model

Modeling the energy savings of clothes washers is complex because energy can be saved by reducing the consumption of the motor, hot water use, or dryer energy use. The most efficient new technology is the horizontal-axis design, which achieves the bulk of its energy savings by reducing hot water use.

The residential NEMS-PNNL input file (RTEKTY) includes a column of factors that relate to hot water. The (unitless) factors can be used to adjust the hot water load associated with clothes washers and dishwashers. In preliminary model runs, the values associated with clothes washers appeared to be too low compared with the information supplied by Lawrence Berkeley National Laboratory (LBNL) in support of an efficiency standard for clothes washers. Therefore, these factors were adjusted from 0.67 to 2.00 for vertical-axis machines. The coefficient for the horizontal-axis machine was increased from 0.24 to 0.40. The value for the vertical axis machine was estimated by making runs of the model with and without *any* hot water and observing the resulting energy consumption. The LBNL analysis suggests that 80% to 90% of the energy consumption of clothes washers is attributable to water heating. Table B-8.1 shows the original and revised NEMS-PNNL inputs for clothes washers.

Market Share Estimates

With the support of the ENERGY STAR project, the Beta1 parameter, which impacts the resulting market share of each clothes washer technology, was modified from -0.03811 to -0.0101 based on this product's project goals. Table B-8.2 shows the market share results of the NEMS-PNNL model runs for clothes washers.

B.8 Energy Star

Gateway Deployment Decision Unit

Modeling the Market for Energy Star Refrigerators

Technology Choices Available in Model

EIA uses four separate models to represent the range of energy efficiencies in the refrigerator market. The first three models are conventional top-mount freezer models with a total capacity of 18 cubic feet. The fourth is a through-the-door model (for water and ice) and does not compete with the first three models. The market share of the through-the-door model is a constant 27% over the forecast horizon. A review of Arthur D. Little's[3] (ADL 1998) efficiency and cost forecasts, as well as a recent paper from Oak Ridge National Laboratory[4] (ORNL, Vineyard and Sand 1998), suggests some changes to EIA's assumptions used in the *Annual Energy Outlook 2001*[2] projection are warranted.

Table B-8.1. Original and Revised NEMS-PNNL Inputs for Energy Star Clothes Washers

Technology	Start Yr	End Yr	Water Coeff.	Energy Factor	Installed Cost ($)	Type
Original NEMS Inputs						
1	1997	2020	0.67	2.71	90	V-Axis
2	1997	2004	0.67	3.88	645	V-Axis
3	2005	2020	0.67	3.88	590	V-Axis
4	1997	2020	0.24	4.45	800	H-Axis
5	2005	2020	0.24	5.27	800	H-Axis
6	2015	2020	0.24	5.44	800	H-Axis
NEMS-PNNL Inputs						
1	1997	2020	2.0	2.71	490	V-Axis
2	1997	2004	2.0	3.88	645	V-Axis
3	2005	2020	2.0	3.88	590	V-Axis
4	1997	2020	0.4	4.45	800	H-Axis
5	2005	2020	0.4	5.27	800	H-Axis
6	2015	2020	0.4	5.44	800	H-Axis

B.8 Energy Star

Gateway Deployment Decision Unit

Table B-8.2. Energy Star Clothes Washer Market Shares by Technology Estimated by NEMS-PNNL

Census Division	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
1	0.0000	0.0927	0.0000	0.0923
2	0.0000	0.0904	0.0000	0.0900
3	0.0000	0.0814	0.0000	0.0804
4	0.0000	0.0794	0.0000	0.0794
5	0.0000	0.0813	0.0000	0.0812
6	0.0000	0.0799	0.0000	0.0797
7	0.0000	0.0801	0.0000	0.0791
8	0.0000	0.0831	0.0000	0.0833
9	0.0000	0.0826	0.0000	0.0830
Note: Results shown are for new housing units; replacement shares are generally within 0.5 % of values shown here.				

As part of the EIA forecast, the 2001 standard (Model 1) was assumed to yield no increase in cost. Table B-8.3 shows the EIA efficiency and cost assumptions, which appear to contradict some of the ADL findings. The ADL performance/cost characteristics information suggests that a 460-kWh/yr unit would have an installed cost of $580 to $700. To be conservative, an installation cost of $600 could be assumed. Because a 478-kWh/yr

Table B-8.3. Refrigerator Efficiency and Costs: *Annual Energy Outlook 2001*

Model	Initial Year	Ending Year	Annual Consumption (kWh)	Installed Cost ($1998)	Retail Cost ($1998)
1	1997	2001	690	530.0	480.0
1	2002	2020	478	530.0	480.0
2	1997	2001	660	550.0	500.0
2	2002	2020	460	550.0	500.0
3	1993	2001	518	850.0	800.0
3	2002	2020	460	550.0	500.0
3	2005	2020	400	700.0	650.0
4	1993	2001	843	1313.8	1313.8
4	2002	2020	577	1313.8	1313.8

unit is nearly as efficient as the 460-kWh/yr unit, one would expect it would be only negligibly less expensive. Using this logic, the cost of the 478-kWh/yr unit is assumed to be ~$580. These revised assumptions are included in Table B-8.4.

B.8 Energy Star

Gateway Deployment Decision Unit

Table B-8.4. Refrigerator Efficiency and Costs: NEMS-PNNL

Model	Initial Year	Ending Year	Annual Consumption (kWh)	Installed Cost ($1998)	Retail Cost ($1998)
1	1997	2001	690	530.0	480.0
1	2002	2020	478	580.0	480.0
2	1997	2001	660	550.0	500.0
2	2002	2020	460	600.0	550.0
3	1997	2001	518	850.0	800.0
3	2002	2020	460	600.0	550.0
3	2005	2020	400	700.0	650.0
4	1997	2001	843	1313.8	1313.8
4	2002	2020	577	1313.8	1313.8

The ADL report[3] suggests that a 460-kWh/yr model represents a typical model after 2002. A high-efficiency model is specified to consume 400 kWh per year. However, this specification is for a 20-cubic-foot model rather than 18 cubic feet. ADL suggests a cost differential of $100 to $120 between these two models.

Vineyard and Sand (1998)[4] add some support to this revision in the cost structure. They start with a "1996 model baseline unit" of 20 cubic feet that uses 613 kWh/year. The baseline is already 16% more efficient than the 1993 standard (2.01 kWh/day) resulting from the National Appliance Energy Conservation Act.[5] From this baseline, they focus on two high-efficiency designs. The most aggressive design would reduce energy by 273 kWh/yr at a retail cost increase of ~$270. A more cost-effective unit would consume 1.16 kWh/day (423 kWh/yr) at a projected cost increase of $106.

Given this information, the resulting estimated cost increase of $100 between the 460- and 400-kWh/day units appears to be more reasonable (see Table B-8.4) than EIA's incremental cost of $150. The ORNL baseline unit is less efficient than the 2001 standard and achieves a 30% energy reduction with a little more than a $100 cost increase. This suggests that the 13% efficiency improvement (460 to 400) between models 2 and 3 could be achieved for $100 or less.

Market Share Estimates

The *Annual Energy Outlook 2001*[2] baseline parameters that determined the market share for high efficiency clothes washers are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0229}{-0.1207} \approx discount\ rate = 19\%$$

B.8 Energy Star

Gateway Deployment Decision Unit

The ENERGY STAR project is assumed to increase the market share of the 400-kWh/yr refrigerator. With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0055}{-0.1207} \approx discount\ rate^{E-Star} = 5\%$$

The resulting NEMS-PNNL market shares for ENERGY STAR refrigerators for 2005 and 2010 are shown in Table B-8.5.

Modeling the Market for Energy Star Hot Water Heaters

PNNL made separate sets of NEMS-PNNL runs for electric water heaters and gas water heaters to model the effects of ENERGY STAR technologies.

Electric Water Heating Technologies Available in Model

Table B-8.6 shows EIA's key NEMS inputs for the *Annual Energy Outlook 2001*.[2] With these assumed costs, the model projects a zero share for heat pump water heaters.

Table B-8.5. Energy Star Project – Refrigerators
(market share of 400-kWh/yr units)

Census Division	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
1	0.0427	0.2068	0.0426	0.2064
2	0.0409	0.2003	0.0400	0.1971
3	0.0337	0.1727	0.0329	0.1698
4	0.0326	0.1687	0.0327	0.1689
5	0.0342	0.1748	0.0341	0.1744
6	0.0330	0.1702	0.0329	0.1696
7	0.0329	0.1698	0.0322	0.1668
8	0.0355	0.1801	0.0356	0.1805
9	0.0354	0.1793	0.0357	0.1807

B.8 Energy Star

Gateway Deployment Decision Unit

Table B-8.6. Key NEMS-PNNL Inputs for Electric Water Heaters (*Annual Energy Outlook 2001*)

Technology	Start Yr	End Yr	Energy Factor	Installed Cost ($)	Type
1	1997	2020	0.86	350	Resistance
2	1997	2020	0.88	350	Resistance
3	1997	2020	0.95	575	Resistance
4	1997	2020	2.60	1,025	Heat Pump
5	1997	2020	2.00	2,600	Heat Pump
6	2005	2020	0.89	350	Resistance
7	2005	2020	0.96	475	Resistance
8	2005	2020	2.00	900	Heat Pump
9	2015	2020	0.90	400	Resistance
10	2015	2020	0.96	425	Resistance
11	2015	2020	2.20	800	Heat Pump

The ENERGY STAR project was assumed to target high-efficiency electric water heaters whose efficiencies exceed 0.9. As Table B-8.6 shows, two such units are shown, with efficiencies of 0.95 and 0.96. By 2005, the installed cost of the high-efficiency unit (at the 0.96 efficiency level) is assumed to fall to $475.

Market Share Estimates for Electric Water Heaters

The *Annual Energy Outlook 2001*[2] baseline parameters that determined the market share for high-efficiency clothes washers are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.01619}{-0.01952} \approx discount\ rate = 83\%$$

With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0082}{-0.01952} \approx discount\ rate^{E-Star} = 42\%$$

Table B-8.7 shows the specific NEMS-PNNL market share results.

B.8 Energy Star

Gateway Deployment Decision Unit

Table B-8.7. NEMS-PNNL Results for Energy Star Electric Water Heaters (national market shares for new single-family homes)

Efficiency Level	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
0.95	0.0110	0.0540	0.0110	0.0540
0.96	0.0560	0.1280	0.0560	0.1270
Total	0.0670	0.1820	0.0670	0.1810
Note: Results shown are for new, single-family housing units; replacement shares are generally within 2% of the values shown here.				

Gas Water Heating Technology Choices Available in Model

Table B-8.8 shows EIA's key NEMS-PNNL inputs for the *Annual Energy Outlook 2001*.[2] The ENERGY STAR project was assumed to promote high-efficiency gas water heaters whose energy factors are 0.6 or higher. As Table B-8.8 shows, two such units are shown, with energy factors of 0.6 and 0.63. By 2005, the installed cost of the high-efficiency unit (at the 0.60 energy factor level) is assumed to fall from $400 to $375.

Market Share Estimates for Gas Water Heaters

The *Annual Energy Outlook 2001*[2] baseline parameters that determined the market share for high-efficiency gas water heaters are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.05393}{-0.1136} \approx discount\ rate = 47\%$$

Table B-8.8. Key NEMS-PNNL Inputs for Gas Water Heaters

Technology	Start Yr	End Yr	Energy Factor	Installed Cost	Type
1	1997	2020	0.54	$340	Noncondensing
2	1997	2020	0.58	$370	Noncondensing
3	1997	2004	0.60	$400	Noncondensing
4	2005	2020	0.60	$375	Noncondensing
5	1997	2020	0.86	$2360	Condensing
6	2005	2014	0.86	$2000	Condensing
7	2015	2020	0.86	$1800	Condensing
8	2005	2014	0.63	$450	Noncondensing
9	2015	2020	0.63	$425	Noncondensing
10	2015	2020	0.70	$500	Noncondensing

B.8 Energy Star

Gateway Deployment Decision Unit

With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0323}{-0.1136} \approx discount\ rate^{E-Star} = 28\%$$

Table B-8.9 shows the specific NEMS-PNNL market share results.

Table B-8.9. NEMS-PNNL Results for Energy Star Gas Water Heaters (national market shares for new, single-family homes)

Efficiency Level	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
0.60	0.307	0.387	0.315	0.384
0.63	0.011	0.068	0.011	0.066
Total	0.318	0.455	0.326	0.450

Energy Star Room Air Conditioners

Technology Choices Available in Model

For the year 2005, EIA assumes that efficiencies of room air conditioners will range from a low of 2.83 COP (seasonal energy efficiency ratio) to a high of 3.52 COP. In the *Annual Energy Outlook 2001*[2] input file for the residential NEMS-PNNL module, two models were at the low end of this range (COP = 2.83, COP = 2.93), while two models were at the high end of the range (COP = 3.22, COP = 3.43). To achieve a more realistic set of choices, a model with an intermediate efficiency of 3.11 was added and the unit at the 2.93 (COP) level was dropped. The increase in cost to go from a COP of 2.83 to 2.93 was assumed to be $30. Table B-8.10 shows both the original NEMS-PNNL input data and the revised data.

The high-efficiency units with a COP >3.4 were assumed to fall under the ENERGY STAR project. In the base case, the combined market share for the units with COPs of 3.43 and 3.52 were <1%. The split in market share between the lowest and intermediate efficiency unit (COP = 2.83 and 3.11, respectively) was generally ~75%/25% in favor of the lowest efficiency model.

Market Share Estimates

The *Annual Energy Outlook 2001*[2] baseline parameters that determined the market share for high-efficiency room air conditioners are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0170}{-0.0120} \approx discount\ rate > 100\%$$

B.8 Energy Star

Gateway Deployment Decision Unit

Table B-8.10. NEMS-PNNL Input Parameters for Room Air Conditioners

Technology	Start Year	End Year	Seasonal COP	SEER*	Installed Cost
Annual Energy Outlook 2001 and GPRA Baseline					
1	1997	2000	2.55	8.70	$450
2	2001	2020	2.83	9.66	$450
3	1997	2004	2.93	10.00	$500
4	2005	2020	2.93	10.00	$490
5	1997	2020	3.43	11.71	$760
6	2005	2020	3.43	11.71	$760
7	2015	2020	3.22	10.99	$600
Revised NEMS-PNNL Inputs					
1	1997	2000	2.55	8.70	$450
2	2001	2020	2.83	9.66	$450
3	1997	2004	3.11	10.61	$530
4	2005	2020	3.11	10.61	$520
5	1997	2020	3.43	11.71	$760
6	2005	2020	3.52	12.01	$760
7	2015	2020	3.22	10.99	$600
*SEER – seasonal energy efficiency ratio.					

With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0070}{-0.0120} \approx discount\ rate^{E-Star} = 58\%$$

Table B-8.11 shows the specific NEMS-PNNL market share results for the high-efficiency model.

B.8 Energy Star

Gateway Deployment Decision Unit

Table B-8.11. NEMS-PNNL Results for Energy Star Room Air Conditioners (market shares for new, single-family homes)

Census Division	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
1	0.0083	0.1301	0.0083	0.1299
2	0.0085	0.1323	0.0085	0.1321
3	0.0085	0.1319	0.0084	0.1314
4	0.0084	0.1314	0.0084	0.1312
5	0.0091	0.1396	0.0091	0.1395
6	0.0091	0.1402	0.0091	0.1398
7	0.0101	0.1522	0.0099	0.1501
8	0.0085	0.1327	0.0085	0.1327
9	0.0084	0.1314	0.0084	0.1317

Modeling the Market for Energy Star Dishwashers

Technology Choices Available in Model

The NEMS-PNNL baseline (*Annual Energy Outlook 2001*)[2] data input for the year 2005 shows three dishwashers, with energy factors 0.46, 0.59, and 0.71. Table B-8.12 shows the associated costs of these units. Given the cost structure and logit choice parameters, the model suggests that consumers select slightly more than 6% of dishwashers with the 0.59 energy factor and virtually none of the very high efficiency units.

Table B-8.12. Key NEMS-PNNL Data Inputs for Dishwashers

Census Division	Initial Yr	Ending Yr	Water Co-Efficiency	Energy Factor	Installed Cost ($)
1	1997	2020	0.80	0.46	350
2	1997	2004	0.80	0.59	500
3	2005	2020	0.80	0.59	450
4	1997	2004	0.78	0.71	700
5	2005	2014	0.78	0.71	600
6	2015	2020	0.78	0.71	500
7	2015	2020	0.80	0.60	400

Market Share Estimates

The *Annual Energy Outlook 2001*[2] baseline parameters that determined the market share for high efficiency dishwashers are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.02738}{-0.02413} \approx discount\ rate > 100\%$$

B.8 Energy Star

Gateway Deployment Decision Unit

With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.01338}{-0.02413} \approx discount\ rate^{E-Star} = 55\%$$

Table B-8.13 shows the specific NEMS-PNNL market share results for the two high-efficiency models.

Table B-8.13. Energy Star Project Dishwashers (estimated market shares for high-efficiency dishwashers)

Census Division	2005				2010			
	Baseline		Energy Star		Baseline		Energy Star	
	EF=.59	EF=.71	EF=.59	EF=.71	EF=.59	EF=.71	EF=.59	EF=.71
1	0.0683	0.0012	0.2219	0.0322	0.0682	0.0012	0.2217	0.0321
2	0.0678	0.0012	0.2207	0.0318	0.0677	0.0012	0.2204	0.0317
3	0.0659	0.0011	0.2157	0.0305	0.0656	0.0011	0.2151	0.0304
4	0.0654	0.0011	0.2146	0.0302	0.0654	0.0011	0.2145	0.0304
5	0.0658	0.0011	0.2156	0.0305	0.0654	0.0011	0.2145	0.0304
6	0.0655	0.0011	0.2148	0.0303	0.0658	0.0011	0.2156	0.0305
7	0.0656	0.0011	0.2150	0.0303	0.0653	0.0011	0.2144	0.0302
8	0.0662	0.0011	0.2166	0.0308	0.0663	0.0012	0.2168	0.0308
9	0.0661	0.0011	0.2164	0.0307	0.0663	0.0012	0.2169	0.0308
EF – energy factor.								

Energy Star Projects Modeled with BESET

Energy Star CFLs

PNNL modeled the ENERGY STAR CFLs in BESET and assumed they would capture 10.5% of incandescent sales in the residential sectors by 2020 (based on market penetration goal of capturing 20% of the installed base). ENERGY STAR CFLs were assumed to penetrate the high-use part of the market where 76.4% of the residential lighting energy is consumed (e.g., rooms such as kitchens and living rooms). The sockets in high-use areas (28.3% of the total sockets) will use roughly the same fraction of the lamps (i.e., 28.3% of the sockets consume 76.4% of the lighting energy use). A sales fraction of 10.5% will yield a long-term installed base of 20% in high-use sockets.

Performance Objective:

- **Displaced Technology:** Incandescent light bulbs.
- **Performance Target:** 51.3 lumens/watt.

Market Penetration:

- **Target Market:** Residential sector.

B.8 Energy Star

Gateway Deployment Decision Unit

- **Market Penetration Goal:** 10.5% of incandescent sales in the residential sectors by 2020 (see Figure B-8.1).

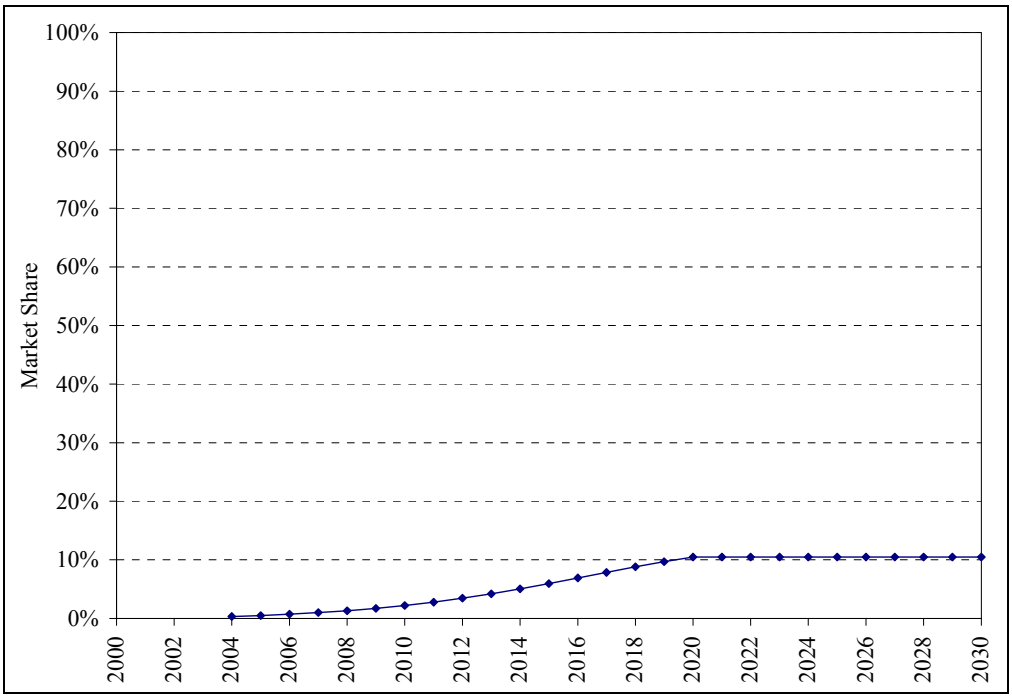

Figure B-8.1. Market Penetration Curves for Energy Star CFLs

Project/Technology Consumer Costs (PNNL Estimate):

- Cost of Conventional Technology: $0.75
- Cost of WIP Technology: Assumed to decrease over study period from approximately $7.00 per CFL in 2004 declining to $3.00 per CFL in 2030.
- Incremental Cost: Varies by year.

Non-Energy Benefits:[1]

- Increased comfort for residential homeowners
- Decreased times spent changing out incandescent lamps
- Water and water bill savings from higher efficiency dishwashers and clothes washers
- Increased amenities with clothes washers, also decreased time required for dryer cycle
- Higher profits for manufacturers.

B.8 Energy Star

Gateway Deployment Decision Unit

Sources:

(1) *FY 2002 Budget Request – Data Bucket Report for Energy Star Program* (internal BTS document).

(2) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.

(3) Arthur D. Little, Inc. (ADL). 1998. "EIA Technology Forecast Updates – Residential and Commercial Building Technologies, Reference Case."

(4) Vineyard, E.A. and J.R. Sand. 1998. "Fridge of the Future: Designing a One Kilowatt-Hour/Day Domestic Refrigerator Freezer." In *1998 ACEEE Summer Study Proceedings*.

(5) National Appliance Energy Conservation Act of 1987, Public Law 100-12.

Appendix C – Baseline Inputs for BESET

To obtain the GPRA metrics for FY 2004, the following baseline scenario and inputs were used. The development of these inputs is discussed in the GPRA Methodology section within the body of this document. This information is common to all projects analyzed within BESET.

C.1 Building Stock

Building stock estimates are used to estimate each project's total energy savings at the national level. Residential and commercial new and existing building stock totals for all years through 2020 were provided by EIA's *Annual Energy Outlook 2002*. The stock estimates were developed for each market segment (e.g., building type, building vintage, and region) based on the assumptions outlined in Section 1.0, "GPRA Methodology." The base year is 2004, and all construction beginning with 2004 is considered "new." Tables C.1 through C.14 present the in-year building stock forecasts by building type, building vintage, and region.

Abbreviations used in the tables in this appendix are as follows:

CAC	central air conditioner
CFL	compact fluorescent light
EE	energy efficient
Elec	electric
FA	forced air
Fluor	fluorescent
Furn	furnace
HE	high efficiency
HID	high-intensity discharge
HP	heat pump
Incan	incandescent
Room	room air conditioner
Std	standard
WH	water heater

C.1.1 Commercial Building Stock Forecasts

Table C.1. Commercial Assembly Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	4.24	2.95	0.10	0.08
2005	4.18	2.91	0.10	0.08
2006	4.12	2.87	0.10	0.08
2007	4.06	2.82	0.10	0.08
2008	4.00	2.78	0.10	0.08
2009	3.94	2.74	0.10	0.08
2010	3.88	2.70	0.10	0.08
2011	3.82	2.65	0.10	0.08
2012	3.75	2.61	0.10	0.08
2013	3.69	2.56	0.10	0.08
2014	3.63	2.52	0.10	0.09
2015	3.56	2.48	0.10	0.09
2016	3.50	2.43	0.10	0.09
2017	3.43	2.39	0.11	0.09
2018	3.37	2.34	0.11	0.09
2019	3.30	2.29	0.11	0.09
2020	3.24	2.25	0.11	0.09
2021	3.18	2.21	0.11	0.09
2022	3.12	2.16	0.11	0.09
2023	3.06	2.12	0.11	0.09
2024	3.00	2.08	0.11	0.09
2025	2.94	2.04	0.11	0.09
2026	2.89	2.01	0.11	0.09
2027	2.83	1.97	0.11	0.09
2028	2.78	1.93	0.11	0.09
2029	2.72	1.89	0.11	0.09
2030	2.67	1.86	0.11	0.09

Table C.2. Commercial Education Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	5.32	3.70	0.19	0.15
2005	5.24	3.64	0.18	0.15
2006	5.16	3.58	0.18	0.15
2007	5.07	3.53	0.18	0.14
2008	4.99	3.47	0.17	0.14
2009	4.91	3.41	0.17	0.14
2010	4.82	3.35	0.17	0.14
2011	4.74	3.29	0.16	0.13
2012	4.65	3.23	0.16	0.13
2013	4.57	3.17	0.16	0.13
2014	4.48	3.12	0.16	0.13
2015	4.40	3.06	0.15	0.12
2016	4.31	3.00	0.15	0.12
2017	4.23	2.94	0.14	0.12
2018	4.15	2.88	0.13	0.11
2019	4.06	2.82	0.13	0.10
2020	3.98	2.77	0.12	0.10
2021	3.90	2.71	0.13	0.11
2022	3.82	2.66	0.13	0.11
2023	3.75	2.60	0.13	0.11
2024	3.67	2.55	0.13	0.11
2025	3.60	2.50	0.13	0.11
2026	3.53	2.45	0.13	0.11
2027	3.46	2.40	0.13	0.11
2028	3.39	2.36	0.13	0.11
2029	3.32	2.31	0.13	0.11
2030	3.26	2.26	0.13	0.11

Table C.3. Commercial Food Sales Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	0.44	0.31	0.01	0.01
2005	0.44	0.31	0.01	0.01
2006	0.44	0.30	0.01	0.01
2007	0.43	0.30	0.01	0.01
2008	0.43	0.30	0.01	0.01
2009	0.42	0.29	0.01	0.01
2010	0.42	0.29	0.01	0.01
2011	0.41	0.29	0.01	0.01
2012	0.41	0.28	0.01	0.01
2013	0.40	0.28	0.01	0.01
2014	0.39	0.27	0.01	0.01
2015	0.39	0.27	0.01	0.01
2016	0.38	0.27	0.01	0.01
2017	0.38	0.26	0.01	0.01
2018	0.37	0.26	0.01	0.01
2019	0.37	0.25	0.01	0.01
2020	0.36	0.25	0.01	0.01
2021	0.35	0.25	0.01	0.01
2022	0.35	0.24	0.01	0.01
2023	0.34	0.24	0.01	0.01
2024	0.34	0.23	0.01	0.01
2025	0.33	0.23	0.01	0.01
2026	0.33	0.23	0.01	0.01
2027	0.32	0.22	0.01	0.01
2028	0.32	0.22	0.01	0.01
2029	0.31	0.22	0.01	0.01
2030	0.31	0.21	0.01	0.01

Table C.4. Commercial Food Service Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	0.91	0.63	0.02	0.02
2005	0.90	0.62	0.02	0.02
2006	0.89	0.62	0.02	0.02
2007	0.88	0.61	0.02	0.01
2008	0.87	0.60	0.02	0.01
2009	0.85	0.59	0.02	0.01
2010	0.84	0.59	0.02	0.02
2011	0.83	0.58	0.02	0.02
2012	0.82	0.57	0.02	0.01
2013	0.81	0.56	0.02	0.01
2014	0.80	0.55	0.02	0.01
2015	0.79	0.55	0.02	0.01
2016	0.77	0.54	0.02	0.01
2017	0.76	0.53	0.02	0.01
2018	0.75	0.52	0.02	0.01
2019	0.74	0.51	0.02	0.02
2020	0.73	0.50	0.02	0.02
2021	0.72	0.50	0.02	0.01
2022	0.70	0.49	0.02	0.01
2023	0.69	0.48	0.02	0.01
2024	0.68	0.47	0.02	0.01
2025	0.67	0.47	0.02	0.01
2026	0.66	0.46	0.02	0.01
2027	0.65	0.45	0.02	0.01
2028	0.64	0.44	0.02	0.01
2029	0.63	0.44	0.02	0.01
2030	0.62	0.43	0.02	0.01

Table C.5. Commercial Health Care Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	1.17	0.81	0.04	0.03
2005	1.16	0.81	0.04	0.03
2006	1.15	0.80	0.04	0.03
2007	1.14	0.79	0.04	0.03
2008	1.13	0.78	0.04	0.03
2009	1.12	0.78	0.04	0.03
2010	1.10	0.77	0.04	0.03
2011	1.09	0.76	0.04	0.03
2012	1.08	0.75	0.04	0.03
2013	1.06	0.74	0.04	0.04
2014	1.05	0.73	0.04	0.04
2015	1.03	0.72	0.05	0.04
2016	1.02	0.71	0.05	0.04
2017	1.00	0.70	0.05	0.04
2018	0.99	0.69	0.05	0.04
2019	0.97	0.67	0.05	0.04
2020	0.95	0.66	0.05	0.04
2021	0.94	0.65	0.05	0.04
2022	0.92	0.64	0.05	0.04
2023	0.91	0.63	0.05	0.04
2024	0.89	0.62	0.05	0.04
2025	0.88	0.61	0.05	0.04
2026	0.86	0.60	0.05	0.04
2027	0.85	0.59	0.05	0.04
2028	0.83	0.58	0.05	0.04
2029	0.82	0.57	0.05	0.04
2030	0.81	0.56	0.05	0.04

Table C.6. Commercial Lodging Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	2.54	1.76	0.08	0.06
2005	2.51	1.74	0.07	0.06
2006	2.48	1.72	0.07	0.06
2007	2.45	1.70	0.07	0.06
2008	2.42	1.69	0.07	0.06
2009	2.40	1.66	0.08	0.06
2010	2.37	1.64	0.08	0.07
2011	2.33	1.62	0.08	0.07
2012	2.30	1.60	0.09	0.07
2013	2.27	1.58	0.09	0.07
2014	2.24	1.56	0.09	0.07
2015	2.21	1.53	0.09	0.07
2016	2.17	1.51	0.09	0.07
2017	2.14	1.49	0.09	0.07
2018	2.10	1.46	0.09	0.07
2019	2.07	1.44	0.09	0.07
2020	2.03	1.41	0.09	0.07
2021	2.00	1.39	0.09	0.07
2022	1.97	1.37	0.09	0.07
2023	1.94	1.35	0.09	0.07
2024	1.90	1.32	0.09	0.07
2025	1.87	1.30	0.09	0.07
2026	1.84	1.28	0.09	0.07
2027	1.81	1.26	0.09	0.07
2028	1.78	1.24	0.09	0.07
2029	1.76	1.22	0.09	0.07
2030	1.73	1.20	0.09	0.07

Table C.7. Commercial Mercantile and Service Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	8.56	5.95	0.21	0.17
2005	8.46	5.88	0.20	0.16
2006	8.36	5.81	0.20	0.16
2007	8.26	5.74	0.19	0.16
2008	8.16	5.67	0.19	0.16
2009	8.06	5.60	0.20	0.16
2010	7.96	5.53	0.20	0.16
2011	7.85	5.45	0.20	0.16
2012	7.74	5.38	0.20	0.16
2013	7.63	5.30	0.19	0.16
2014	7.52	5.23	0.19	0.15
2015	7.41	5.15	0.19	0.15
2016	7.30	5.07	0.19	0.15
2017	7.18	4.99	0.19	0.16
2018	7.06	4.91	0.20	0.16
2019	6.95	4.83	0.20	0.16
2020	6.83	4.74	0.19	0.16
2021	6.71	4.67	0.19	0.16
2022	6.61	4.59	0.19	0.16
2023	6.50	4.52	0.19	0.16
2024	6.39	4.44	0.19	0.16
2025	6.29	4.37	0.19	0.16
2026	6.19	4.30	0.19	0.16
2027	6.08	4.23	0.19	0.16
2028	5.99	4.16	0.19	0.16
2029	5.89	4.09	0.19	0.16
2030	5.79	4.02	0.19	0.16

Table C.8. Commercial Office—Large Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	3.71	2.58	0.08	0.07
2005	3.67	2.55	0.08	0.06
2006	3.64	2.53	0.08	0.06
2007	3.61	2.51	0.07	0.06
2008	3.57	2.48	0.07	0.06
2009	3.54	2.46	0.07	0.06
2010	3.50	2.43	0.07	0.06
2011	3.46	2.41	0.08	0.06
2012	3.42	2.38	0.08	0.06
2013	3.38	2.35	0.08	0.07
2014	3.34	2.32	0.08	0.07
2015	3.30	2.29	0.08	0.07
2016	3.26	2.26	0.08	0.07
2017	3.21	2.23	0.08	0.07
2018	3.17	2.20	0.08	0.07
2019	3.12	2.17	0.09	0.07
2020	3.07	2.13	0.09	0.07
2021	3.03	2.10	0.08	0.07
2022	2.98	2.07	0.08	0.07
2023	2.94	2.04	0.08	0.07
2024	2.90	2.01	0.08	0.07
2025	2.86	1.99	0.08	0.07
2026	2.82	1.96	0.08	0.07
2027	2.78	1.93	0.08	0.07
2028	2.74	1.90	0.08	0.07
2029	2.70	1.87	0.08	0.07
2030	2.66	1.85	0.08	0.07

Table C.9. Commercial Office—Small Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	3.52	2.44	0.09	0.08
2005	3.48	2.42	0.09	0.07
2006	3.43	2.39	0.08	0.07
2007	3.39	2.36	0.08	0.07
2008	3.35	2.33	0.08	0.06
2009	3.31	2.30	0.08	0.07
2010	3.26	2.27	0.08	0.07
2011	3.22	2.24	0.08	0.07
2012	3.18	2.21	0.09	0.07
2013	3.13	2.18	0.09	0.07
2014	3.09	2.15	0.09	0.07
2015	3.04	2.12	0.09	0.07
2016	3.00	2.08	0.09	0.07
2017	2.96	2.05	0.09	0.07
2018	2.91	2.02	0.09	0.07
2019	2.86	1.99	0.09	0.07
2020	2.82	1.96	0.09	0.07
2021	2.77	1.93	0.09	0.07
2022	2.73	1.90	0.09	0.07
2023	2.69	1.87	0.09	0.07
2024	2.65	1.84	0.09	0.07
2025	2.61	1.81	0.09	0.07
2026	2.57	1.78	0.09	0.07
2027	2.53	1.76	0.09	0.07
2028	2.49	1.73	0.09	0.07
2029	2.45	1.70	0.09	0.07
2030	2.41	1.68	0.09	0.07

Table C.10. Commercial Other Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	3.61	2.51	0.17	0.14
2005	3.57	2.48	0.17	0.14
2006	3.52	2.45	0.17	0.14
2007	3.48	2.42	0.16	0.13
2008	3.43	2.38	0.16	0.13
2009	3.39	2.35	0.16	0.13
2010	3.34	2.32	0.16	0.13
2011	3.30	2.29	0.16	0.13
2012	3.25	2.26	0.16	0.13
2013	3.21	2.23	0.17	0.14
2014	3.17	2.20	0.17	0.14
2015	3.12	2.17	0.17	0.14
2016	3.08	2.14	0.17	0.14
2017	3.03	2.11	0.17	0.14
2018	2.99	2.08	0.16	0.13
2019	2.94	2.04	0.16	0.13
2020	2.90	2.01	0.16	0.13
2021	2.85	1.98	0.16	0.13
2022	2.81	1.95	0.16	0.13
2023	2.77	1.93	0.16	0.13
2024	2.73	1.90	0.16	0.13
2025	2.69	1.87	0.16	0.13
2026	2.65	1.84	0.16	0.13
2027	2.61	1.81	0.16	0.13
2028	2.57	1.79	0.16	0.13
2029	2.54	1.76	0.16	0.13
2030	2.50	1.74	0.16	0.13

Table C.11. Commercial Warehouse Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	6.23	4.33	0.20	0.17
2005	6.17	4.29	0.19	0.15
2006	6.11	4.25	0.18	0.15
2007	6.05	4.20	0.17	0.14
2008	5.99	4.16	0.16	0.13
2009	5.92	4.12	0.16	0.13
2010	5.86	4.07	0.19	0.16
2011	5.79	4.03	0.21	0.17
2012	5.73	3.98	0.22	0.18
2013	5.66	3.93	0.23	0.18
2014	5.59	3.88	0.22	0.18
2015	5.52	3.83	0.21	0.17
2016	5.45	3.78	0.21	0.17
2017	5.37	3.73	0.21	0.17
2018	5.30	3.68	0.21	0.17
2019	5.22	3.63	0.21	0.17
2020	5.15	3.58	0.21	0.17
2021	5.07	3.53	0.21	0.17
2022	5.00	3.48	0.21	0.17
2023	4.93	3.43	0.21	0.17
2024	4.87	3.38	0.21	0.17
2025	4.80	3.33	0.21	0.17
2026	4.73	3.29	0.21	0.17
2027	4.67	3.24	0.21	0.17
2028	4.60	3.20	0.21	0.17
2029	4.54	3.15	0.21	0.17
2030	4.48	3.11	0.21	0.17

C.1.2 Residential Building Stock Forecasts

Table C.12. Residential Mobile Home Building Stock Forecast by Building Vintage and Region (million households)

Year	Existing North	Existing South	New North	New South
2004	3.04	3.29	0.12	0.14
2005	2.93	3.18	0.12	0.15
2006	2.83	3.07	0.12	0.15
2007	2.73	2.96	0.12	0.15
2008	2.64	2.85	0.12	0.15
2009	2.54	2.75	0.12	0.14
2010	2.45	2.66	0.11	0.14
2011	2.37	2.57	0.11	0.13
2012	2.29	2.48	0.10	0.12
2013	2.21	2.39	0.09	0.11
2014	2.13	2.31	0.08	0.10
2015	2.05	2.22	0.08	0.10
2016	1.98	2.15	0.08	0.10
2017	1.91	2.07	0.08	0.09
2018	1.85	2.00	0.07	0.09
2019	1.78	1.93	0.07	0.09
2020	1.72	1.86	0.07	0.09
2021	1.71	1.85	0.07	0.09
2022	1.70	1.85	0.07	0.09
2023	1.70	1.84	0.07	0.09
2024	1.69	1.83	0.07	0.09
2025	1.68	1.82	0.07	0.09
2026	1.68	1.82	0.07	0.09
2027	1.67	1.81	0.07	0.09
2028	1.66	1.80	0.07	0.09
2029	1.66	1.80	0.07	0.09
2030	1.65	1.79	0.07	0.09

Table C.13. Residential Multifamily Building Stock Forecast by Building Vintage and Region (million households)

Year	Existing North	Existing South	New North	New South
2004	13.37	8.91	0.10	0.10
2005	13.32	8.88	0.10	0.10
2006	13.27	8.84	0.09	0.09
2007	13.21	8.81	0.09	0.09
2008	13.16	8.77	0.10	0.10
2009	13.11	8.74	0.10	0.10
2010	13.05	8.70	0.11	0.11
2011	13.00	8.67	0.11	0.11
2012	12.95	8.63	0.10	0.10
2013	12.90	8.60	0.10	0.10
2014	12.85	8.56	0.10	0.10
2015	12.80	8.53	0.11	0.11
2016	12.74	8.50	0.11	0.11
2017	12.69	8.46	0.12	0.12
2018	12.64	8.43	0.12	0.12
2019	12.59	8.39	0.13	0.13
2020	12.54	8.36	0.13	0.13
2021	12.49	8.33	0.12	0.12
2022	12.44	8.29	0.12	0.12
2023	12.39	8.26	0.12	0.12
2024	12.34	8.23	0.12	0.12
2025	12.29	8.20	0.12	0.12
2026	12.24	8.16	0.12	0.12
2027	12.19	8.13	0.12	0.12
2028	12.15	8.10	0.12	0.12
2029	12.10	8.06	0.12	0.12
2030	12.05	8.03	0.12	0.12

Table C.14. Residential Single-Family Building Stock Forecast by Building Vintage and Region (million households)

Year	Existing North	Existing South	New North	New South
2004	47.41	31.61	0.62	0.62
2005	47.22	31.48	0.63	0.63
2006	47.03	31.35	0.62	0.62
2007	46.84	31.23	0.62	0.62
2008	46.65	31.10	0.62	0.62
2009	46.47	30.98	0.63	0.63
2010	46.28	30.85	0.63	0.63
2011	46.10	30.73	0.64	0.64
2012	45.91	30.61	0.62	0.62
2013	45.73	30.49	0.61	0.61
2014	45.54	30.36	0.61	0.61
2015	45.36	30.24	0.62	0.62
2016	45.18	30.12	0.61	0.61
2017	45.00	30.00	0.62	0.62
2018	44.82	29.88	0.62	0.62
2019	44.64	29.76	0.63	0.63
2020	44.46	29.64	0.62	0.62
2021	44.28	29.52	0.62	0.62
2022	44.11	29.41	0.62	0.62
2023	43.93	29.29	0.62	0.62
2024	43.76	29.17	0.62	0.62
2025	43.58	29.05	0.62	0.62
2026	43.41	28.94	0.62	0.62
2027	43.23	28.82	0.62	0.62
2028	43.06	28.71	0.62	0.62
2029	42.89	28.59	0.62	0.62
2030	42.72	28.48	0.62	0.62

C.2 Baseline Equipment Market Shares

Equipment market shares were broken out by market segment and are estimated from the 1997 "Residential Energy Consumption Survey," the 1995 "Commercial Buildings Energy Consumption Survey," and original PNNL efforts by Dave Belzer. Tables C.15 through C.31 present the baseline equipment market shares by building sector, vintage, and region.

C.2.1 Residential Market Shares

Table C.15. Residential Heating Equipment Market Shares – Existing North

Year	Elec FA	Elec HP	Gas HE Furn	Gas HP	Gas Std Furn	Oil Furn	Other
2004	0.12	0.10	0.18	0.01	0.53	0.03	0.02
2005	0.12	0.10	0.18	0.01	0.53	0.03	0.02
2006	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2007	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2008	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2009	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2010	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2011	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2012	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2013	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2014	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2015	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2016	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2017	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2018	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2019	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2020	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2021	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2022	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2023	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2024	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2025	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2026	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2027	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2028	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2029	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2030	0.12	0.10	0.28	0.01	0.43	0.03	0.02

Table C.16. Residential Heating Equipment Market Shares – Existing South

Year	Elec FA	Elec HP	Gas HE Furn	Gas HP	Gas Std Furn	Oil Furn	Other
2004	0.21	0.19	0.15	0.00	0.44	0.01	0.00
2005	0.21	0.19	0.15	0.00	0.44	0.01	0.00
2006	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2007	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2008	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2009	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2010	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2011	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2012	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2013	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2014	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2015	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2016	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2017	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2018	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2019	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2020	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2021	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2022	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2023	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2024	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2025	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2026	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2027	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2028	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2029	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2030	0.21	0.19	0.23	0.00	0.35	0.01	0.00

Table C.17. Residential Heating Equipment Market Shares – New North

Year	Elec FA	Elec HP	Gas HE Furn	Gas HP	Gas Std Furn	Oil Furn	Other
2004	0.08	0.14	0.17	0.02	0.52	0.03	0.04
2005	0.08	0.14	0.17	0.02	0.52	0.03	0.04
2006	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2007	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2008	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2009	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2010	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2011	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2012	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2013	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2014	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2015	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2016	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2017	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2018	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2019	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2020	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2021	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2022	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2023	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2024	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2025	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2026	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2027	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2028	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2029	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2030	0.11	0.17	0.26	0.02	0.36	0.03	0.05

Table C.18. Residential Heating Equipment Market Shares – New South

Year	Elec FA	Elec HP	Gas HE Furn	Gas HP	Gas Std Furn	Oil Furn	Other
2004	0.13	0.28	0.14	0.00	0.43	0.01	0.01
2005	0.13	0.28	0.14	0.00	0.43	0.01	0.01
2006	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2007	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2008	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2009	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2010	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2011	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2012	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2013	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2014	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2015	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2016	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2017	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2018	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2019	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2020	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2021	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2022	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2023	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2024	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2025	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2026	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2027	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2028	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2029	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2030	0.19	0.32	0.20	0.00	0.27	0.01	0.01

Table C.19. Residential Cooling Equipment Market Shares – Existing North

Year	Elec CAC	Elec HP	Elec Room	Gas HP	Other	None
2004	0.60	0.10	0.03	0.01	0.02	0.24
2005	0.60	0.10	0.03	0.01	0.02	0.24
2006	0.60	0.10	0.03	0.01	0.02	0.24
2007	0.60	0.10	0.03	0.01	0.02	0.24
2008	0.60	0.10	0.03	0.01	0.02	0.24
2009	0.60	0.10	0.03	0.01	0.02	0.24
2010	0.60	0.10	0.03	0.01	0.02	0.24
2011	0.60	0.10	0.03	0.01	0.02	0.24
2012	0.60	0.10	0.03	0.01	0.02	0.24
2013	0.60	0.10	0.03	0.01	0.02	0.24
2014	0.60	0.10	0.03	0.01	0.02	0.24
2015	0.60	0.10	0.03	0.01	0.02	0.24
2016	0.60	0.10	0.03	0.01	0.02	0.24
2017	0.60	0.10	0.03	0.01	0.02	0.24
2018	0.60	0.10	0.03	0.01	0.02	0.24
2019	0.60	0.10	0.03	0.01	0.02	0.24
2020	0.60	0.10	0.03	0.01	0.02	0.24
2021	0.60	0.10	0.03	0.01	0.02	0.24
2022	0.60	0.10	0.03	0.01	0.02	0.24
2023	0.60	0.10	0.03	0.01	0.02	0.24
2024	0.60	0.10	0.03	0.01	0.02	0.24
2025	0.60	0.10	0.03	0.01	0.02	0.24
2026	0.60	0.10	0.03	0.01	0.02	0.24
2027	0.60	0.10	0.03	0.01	0.02	0.24
2028	0.60	0.10	0.03	0.01	0.02	0.24
2029	0.60	0.10	0.03	0.01	0.02	0.24
2030	0.60	0.10	0.03	0.01	0.02	0.24

Table C.20. Residential Cooling Equipment Market Shares – Existing South

Year	Elec CAC	Elec HP	Elec Room	Gas HP	Other	None
2004	0.64	0.19	0.02	0.00	0.00	0.14
2005	0.64	0.19	0.02	0.00	0.00	0.14
2006	0.64	0.19	0.02	0.00	0.00	0.14
2007	0.64	0.19	0.02	0.00	0.00	0.14
2008	0.64	0.19	0.02	0.00	0.00	0.14
2009	0.64	0.19	0.02	0.00	0.00	0.14
2010	0.64	0.19	0.02	0.00	0.00	0.14
2011	0.64	0.19	0.02	0.00	0.00	0.14
2012	0.64	0.19	0.02	0.00	0.00	0.14
2013	0.64	0.19	0.02	0.00	0.00	0.14
2014	0.64	0.19	0.02	0.00	0.00	0.14
2015	0.64	0.19	0.02	0.00	0.00	0.14
2016	0.64	0.19	0.02	0.00	0.00	0.14
2017	0.64	0.19	0.02	0.00	0.00	0.14
2018	0.64	0.19	0.02	0.00	0.00	0.14
2019	0.64	0.19	0.02	0.00	0.00	0.14
2020	0.64	0.19	0.02	0.00	0.00	0.14
2021	0.64	0.19	0.02	0.00	0.00	0.14
2022	0.64	0.19	0.02	0.00	0.00	0.14
2023	0.64	0.19	0.02	0.00	0.00	0.14
2024	0.64	0.19	0.02	0.00	0.00	0.14
2025	0.64	0.19	0.02	0.00	0.00	0.14
2026	0.64	0.19	0.02	0.00	0.00	0.14
2027	0.64	0.19	0.02	0.00	0.00	0.14
2028	0.64	0.19	0.02	0.00	0.00	0.14
2029	0.64	0.19	0.02	0.00	0.00	0.14
2030	0.64	0.19	0.02	0.00	0.00	0.14

Table C.21. Residential Cooling Equipment Market Shares – New North

Year	Elec CAC	Elec HP	Elec Room	Gas HP	Other	None
2004	0.55	0.14	0.03	0.02	0.04	0.22
2005	0.55	0.14	0.03	0.02	0.04	0.22
2006	0.54	0.15	0.02	0.02	0.04	0.22
2007	0.54	0.15	0.02	0.02	0.04	0.22
2008	0.54	0.15	0.02	0.02	0.04	0.22
2009	0.54	0.15	0.02	0.02	0.04	0.22
2010	0.54	0.15	0.02	0.02	0.04	0.22
2011	0.53	0.16	0.02	0.02	0.04	0.22
2012	0.53	0.16	0.02	0.02	0.04	0.22
2013	0.53	0.16	0.02	0.02	0.04	0.22
2014	0.53	0.16	0.02	0.02	0.04	0.22
2015	0.53	0.16	0.02	0.02	0.04	0.22
2016	0.52	0.17	0.02	0.02	0.05	0.22
2017	0.52	0.17	0.02	0.02	0.05	0.22
2018	0.52	0.17	0.02	0.02	0.05	0.22
2019	0.52	0.17	0.02	0.02	0.05	0.22
2020	0.52	0.17	0.02	0.02	0.05	0.22
2021	0.52	0.17	0.02	0.02	0.05	0.22
2022	0.52	0.17	0.02	0.02	0.05	0.22
2023	0.52	0.17	0.02	0.02	0.05	0.22
2024	0.52	0.17	0.02	0.02	0.05	0.22
2025	0.52	0.17	0.02	0.02	0.05	0.22
2026	0.52	0.17	0.02	0.02	0.05	0.22
2027	0.52	0.17	0.02	0.02	0.05	0.22
2028	0.52	0.17	0.02	0.02	0.05	0.22
2029	0.52	0.17	0.02	0.02	0.05	0.22
2030	0.52	0.17	0.02	0.02	0.05	0.22

Table C.22. Residential Cooling Equipment Market Shares – New South

Year	Elec CAC	Elec HP	Elec Room	Gas HP	Other	None
2004	0.57	0.28	0.01	0.00	0.01	0.13
2005	0.57	0.28	0.01	0.00	0.01	0.13
2006	0.55	0.29	0.01	0.00	0.01	0.13
2007	0.55	0.29	0.01	0.00	0.01	0.13
2008	0.55	0.29	0.01	0.00	0.01	0.13
2009	0.55	0.29	0.01	0.00	0.01	0.13
2010	0.55	0.29	0.01	0.00	0.01	0.13
2011	0.54	0.30	0.01	0.00	0.01	0.13
2012	0.54	0.30	0.01	0.00	0.01	0.13
2013	0.54	0.30	0.01	0.00	0.01	0.13
2014	0.54	0.30	0.01	0.00	0.01	0.13
2015	0.54	0.30	0.01	0.00	0.01	0.13
2016	0.53	0.32	0.01	0.00	0.01	0.13
2017	0.53	0.32	0.01	0.00	0.01	0.13
2018	0.53	0.32	0.01	0.00	0.01	0.13
2019	0.53	0.32	0.01	0.00	0.01	0.13
2020	0.53	0.32	0.01	0.00	0.01	0.13
2021	0.53	0.32	0.01	0.00	0.01	0.13
2022	0.53	0.32	0.01	0.00	0.01	0.13
2023	0.53	0.32	0.01	0.00	0.01	0.13
2024	0.53	0.32	0.01	0.00	0.01	0.13
2025	0.53	0.32	0.01	0.00	0.01	0.13
2026	0.53	0.32	0.01	0.00	0.01	0.13
2027	0.53	0.32	0.01	0.00	0.01	0.13
2028	0.53	0.32	0.01	0.00	0.01	0.13
2029	0.53	0.32	0.01	0.00	0.01	0.13
2030	0.53	0.32	0.01	0.00	0.01	0.13

Table C.23. Residential Water Heating Equipment Market Shares – All Building Vintages and Regions

Year	Elec WH	Gas WH	Oil WH
2004	0.23	0.73	0.05
2005	0.23	0.73	0.05
2006	0.22	0.73	0.04
2007	0.22	0.73	0.04
2008	0.22	0.73	0.04
2009	0.22	0.73	0.04
2010	0.22	0.73	0.04
2011	0.22	0.74	0.04
2012	0.22	0.74	0.04
2013	0.22	0.74	0.04
2014	0.22	0.74	0.04
2015	0.22	0.74	0.04
2016	0.22	0.74	0.04
2017	0.22	0.74	0.04
2018	0.22	0.74	0.04
2019	0.22	0.74	0.04
2020	0.22	0.74	0.04
2021	0.22	0.74	0.04
2022	0.22	0.74	0.04
2023	0.22	0.74	0.04
2024	0.22	0.74	0.04
2025	0.22	0.74	0.04
2026	0.22	0.74	0.04
2027	0.22	0.74	0.04
2028	0.22	0.74	0.04
2029	0.22	0.74	0.04
2030	0.22	0.74	0.04

Table C.24. Residential Lighting Equipment Market Shares – All Building Vintages and Regions

Year	CFL	EE Fluor	EE Incan	HID	Std Fluor	Std Incan
2004	0.04	0.00	0.00	0.00	0.12	0.85
2005	0.04	0.00	0.00	0.00	0.12	0.85
2006	0.06	0.00	0.00	0.00	0.12	0.82
2007	0.06	0.00	0.00	0.00	0.12	0.82
2008	0.06	0.00	0.00	0.00	0.12	0.82
2009	0.06	0.00	0.00	0.00	0.12	0.82
2010	0.06	0.00	0.00	0.00	0.12	0.82
2011	0.09	0.00	0.00	0.00	0.12	0.80
2012	0.09	0.00	0.00	0.00	0.12	0.80
2013	0.09	0.00	0.00	0.00	0.12	0.80
2014	0.09	0.00	0.00	0.00	0.12	0.80
2015	0.09	0.00	0.00	0.00	0.12	0.80
2016	0.11	0.00	0.00	0.00	0.12	0.77
2017	0.11	0.00	0.00	0.00	0.12	0.77
2018	0.11	0.00	0.00	0.00	0.12	0.77
2019	0.11	0.00	0.00	0.00	0.12	0.77
2020	0.11	0.00	0.00	0.00	0.12	0.77
2021	0.11	0.00	0.00	0.00	0.12	0.77
2022	0.11	0.00	0.00	0.00	0.12	0.77
2023	0.11	0.00	0.00	0.00	0.12	0.77
2024	0.11	0.00	0.00	0.00	0.12	0.77
2025	0.11	0.00	0.00	0.00	0.12	0.77
2026	0.11	0.00	0.00	0.00	0.12	0.77
2027	0.11	0.00	0.00	0.00	0.12	0.77
2028	0.11	0.00	0.00	0.00	0.12	0.77
2029	0.11	0.00	0.00	0.00	0.12	0.77
2030	0.11	0.00	0.00	0.00	0.12	0.77

C.2.2 Commercial Market Shares

Table C.25. Commercial Heating Equipment Market Shares – Existing North

Year	Elec FA	Elec HP	Gas HE Furn	Gas Std Furn	Oil Furn	Other	None
2004	0.08	0.04	0.12	0.36	0.10	0.10	0.20
2005	0.08	0.04	0.12	0.36	0.10	0.10	0.20
2006	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2007	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2008	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2009	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2010	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2011	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2012	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2013	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2014	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2015	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2016	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2017	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2018	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2019	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2020	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2021	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2022	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2023	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2024	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2025	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2026	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2027	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2028	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2029	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2030	0.08	0.04	0.19	0.29	0.10	0.10	0.20

Table C.26. Commercial Heating Equipment Market Shares – Existing South

Year	Elec FA	Elec HP	Gas HE Furn	Gas Std Furn	Oil Furn	Other	None
2004	0.20	0.06	0.10	0.29	0.01	0.04	0.31
2005	0.20	0.06	0.10	0.29	0.01	0.04	0.31
2006	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2007	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2008	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2009	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2010	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2011	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2012	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2013	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2014	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2015	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2016	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2017	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2018	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2019	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2020	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2021	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2022	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2023	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2024	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2025	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2026	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2027	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2028	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2029	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2030	0.20	0.06	0.15	0.23	0.01	0.04	0.31

Table C.27. Commercial Heating Equipment Market Shares – New North

Year	Elec FA	Elec HP	Gas HE Furn	Gas Std Furn	Oil Furn	Other	None
2004	0.14	0.08	0.12	0.36	0.05	0.08	0.19
2005	0.14	0.08	0.12	0.36	0.05	0.08	0.19
2006	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2007	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2008	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2009	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2010	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2011	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2012	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2013	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2014	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2015	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2016	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2017	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2018	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2019	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2020	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2021	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2022	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2023	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2024	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2025	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2026	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2027	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2028	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2029	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2030	0.14	0.08	0.19	0.28	0.05	0.08	0.19

Table C.28. Commercial Heating Equipment Market Shares – New South

Year	Elec FA	Elec HP	Gas HE Furn	Gas Std Furn	Oil Furn	Other	None
2004	0.28	0.09	0.07	0.22	0.00	0.08	0.26
2005	0.28	0.09	0.07	0.22	0.00	0.08	0.26
2006	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2007	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2008	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2009	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2010	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2011	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2012	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2013	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2014	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2015	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2016	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2017	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2018	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2019	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2020	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2021	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2022	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2023	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2024	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2025	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2026	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2027	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2028	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2029	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2030	0.28	0.09	0.12	0.18	0.00	0.08	0.26

Table C.29. Commercial Cooling Equipment Market Shares*

Equipment	Exist North	Exist South	New North	New South
Elec CAC	0.23	0.29	0.34	0.25
Elec Chiller	0.11	0.14	0.11	0.20
Elec HP	0.04	0.06	0.08	0.09
Elec Room	0.05	0.06	0.02	0.11
Gas Chiller	0.01	0.01	0.00	0.00
Other	0.04	0.06	0.04	0.04
None	0.52	0.38	0.41	0.31

*Market shares for commercial cooling are constant throughout the analysis period so are not presented by year.

Table C.30. Commercial Water Heating Equipment Market Shares – All Building Vintages and Regions

Year	Elec WH	Gas WH	Oil WH
2004	0.11	0.83	0.07
2005	0.11	0.83	0.07
2006	0.13	0.82	0.04
2007	0.13	0.82	0.04
2008	0.13	0.82	0.04
2009	0.13	0.82	0.04
2010	0.13	0.82	0.04
2011	0.15	0.81	0.04
2012	0.15	0.81	0.04
2013	0.15	0.81	0.04
2014	0.15	0.81	0.04
2015	0.15	0.81	0.04
2016	0.17	0.79	0.04
2017	0.17	0.79	0.04
2018	0.17	0.79	0.04
2019	0.17	0.79	0.04
2020	0.17	0.79	0.04
2021	0.17	0.79	0.04
2022	0.17	0.79	0.04
2023	0.17	0.79	0.04
2024	0.17	0.79	0.04
2025	0.17	0.79	0.04
2026	0.17	0.79	0.04
2027	0.17	0.79	0.04
2028	0.17	0.79	0.04
2029	0.17	0.79	0.04
2030	0.17	0.79	0.04

Table C.31. Commercial Lighting Equipment Market Shares – All Building Vintages and Regions

Year	CFL	EE Fluor	EE Incan	HID	Std Fluor	Std Incan
2004	0.04	0.31	0.12	0.04	0.28	0.22
2005	0.04	0.31	0.12	0.04	0.28	0.22
2006	0.06	0.31	0.12	0.04	0.28	0.19
2007	0.06	0.31	0.12	0.04	0.28	0.19
2008	0.06	0.31	0.12	0.04	0.28	0.19
2009	0.06	0.31	0.12	0.04	0.28	0.19
2010	0.06	0.31	0.12	0.04	0.28	0.19
2011	0.09	0.31	0.12	0.04	0.28	0.17
2012	0.09	0.31	0.12	0.04	0.28	0.17
2013	0.09	0.31	0.12	0.04	0.28	0.17
2014	0.09	0.31	0.12	0.04	0.28	0.17
2015	0.09	0.31	0.12	0.04	0.28	0.17
2016	0.11	0.31	0.12	0.04	0.28	0.14
2017	0.11	0.31	0.12	0.04	0.28	0.14
2018	0.11	0.31	0.12	0.04	0.28	0.14
2019	0.11	0.31	0.12	0.04	0.28	0.14
2020	0.11	0.31	0.12	0.04	0.28	0.14
2021	0.11	0.31	0.12	0.04	0.28	0.14
2022	0.11	0.31	0.12	0.04	0.28	0.14
2023	0.11	0.31	0.12	0.04	0.28	0.14
2024	0.11	0.31	0.12	0.04	0.28	0.14
2025	0.11	0.31	0.12	0.04	0.28	0.14
2026	0.11	0.31	0.12	0.04	0.28	0.14
2027	0.11	0.31	0.12	0.04	0.28	0.14
2028	0.11	0.31	0.12	0.04	0.28	0.14
2029	0.11	0.31	0.12	0.04	0.28	0.14
2030	0.11	0.31	0.12	0.04	0.28	0.14

C.3 Baseline Equipment Efficiencies

The efficiency of equipment stock was developed from EIA's 1995 *Annual Energy Outlook* and input from DOE project managers. Where applicable, the assumed stock efficiency increased to meet equipment standards. Tables C.32 through C.39 present the baseline equipment efficiencies by building sector.

C.3.1 Residential Equipment Efficiencies

Table C.32. Residential Heating Equipment Efficiencies

Year	Elec FA (AFUE)	Elec HP (COP)	Gas HE Furn (AFUE)	Gas HP (COP)	Gas Std Furn (AFUE)	Oil Furn (AFUE)
2004	1.00	2.12	0.92	1.40	0.78	0.80
2005	1.00	2.12	0.92	1.40	0.78	0.81
2006	1.00	2.12	0.92	1.40	0.78	0.81
2007	1.00	2.12	0.92	1.40	0.78	0.81
2008	1.00	2.12	0.92	1.40	0.78	0.81
2009	1.00	2.12	0.92	1.40	0.78	0.81
2010	1.00	2.12	0.92	1.40	0.78	0.81
2011	1.00	2.12	0.92	1.40	0.78	0.82
2012	1.00	2.12	0.92	1.40	0.78	0.82
2013	1.00	2.13	0.92	1.40	0.78	0.82
2014	1.00	2.13	0.92	1.40	0.78	0.82
2015	1.00	2.14	0.92	1.40	0.78	0.82
2016	1.00	2.15	0.92	1.40	0.78	0.82
2017	1.00	2.16	0.92	1.40	0.78	0.82
2018	1.00	2.16	0.92	1.40	0.78	0.82
2019	1.00	2.17	0.92	1.40	0.78	0.82
2020	1.00	2.18	0.92	1.40	0.78	0.82
2021	1.00	2.18	0.92	1.40	0.78	0.82
2022	1.00	2.18	0.92	1.40	0.78	0.82
2023	1.00	2.18	0.92	1.40	0.78	0.82
2024	1.00	2.19	0.92	1.40	0.78	0.82
2025	1.00	2.19	0.92	1.40	0.78	0.82
2026	1.00	2.19	0.92	1.40	0.78	0.82
2027	1.00	2.20	0.92	1.40	0.78	0.82
2028	1.00	2.20	0.92	1.40	0.78	0.82
2029	1.00	2.20	0.92	1.40	0.78	0.82
2030	1.00	2.21	0.92	1.40	0.78	0.82

Table C.33. Residential Cooling Equipment Efficiencies

Year	Elec CAC (COP)	Elec HP (COP)	Elec Room (COP)	Gas HP (COP)
2004	3.13	3.18	2.67	0.95
2005	3.15	3.20	2.70	0.95
2006	3.17	3.21	2.72	0.95
2007	3.18	3.22	2.74	0.95
2008	3.20	3.23	2.76	0.95
2009	3.21	3.24	2.78	0.95
2010	3.22	3.24	2.79	0.95
2011	3.23	3.25	2.80	0.95
2012	3.24	3.25	2.82	0.95
2013	3.25	3.25	2.83	0.95
2014	3.25	3.26	2.84	0.95
2015	3.27	3.26	2.85	0.95
2016	3.29	3.28	2.86	0.95
2017	3.30	3.29	2.86	0.95
2018	3.31	3.31	2.87	0.95
2019	3.32	3.32	2.87	0.95
2020	3.33	3.33	2.87	0.95
2021	3.33	3.33	2.87	0.95
2022	3.33	3.33	2.87	0.95
2023	3.33	3.33	2.87	0.95
2024	3.33	3.33	2.87	0.95
2025	3.33	3.33	2.87	0.95
2026	3.33	3.33	2.87	0.95
2027	3.33	3.33	2.87	0.95
2028	3.33	3.33	2.87	0.95
2029	3.33	3.33	2.87	0.95
2030	3.33	3.33	2.87	0.95

Table C.34. Residential Water Heating Equipment Efficiencies

Year	Elec WH	Gas WH	Oil WH
2004	0.93	0.62	0.55
2005	0.93	0.62	0.55
2006	0.93	0.62	0.56
2007	0.93	0.62	0.56
2008	0.93	0.62	0.56
2009	0.93	0.62	0.56
2010	0.93	0.62	0.56
2011	0.93	0.62	0.56
2012	0.93	0.62	0.56
2013	0.93	0.62	0.56
2014	0.93	0.62	0.56
2015	0.93	0.62	0.56
2016	0.93	0.62	0.56
2017	0.93	0.62	0.56
2018	0.93	0.62	0.56
2019	0.93	0.62	0.56
2020	0.93	0.62	0.56
2021	0.93	0.62	0.56
2022	0.93	0.62	0.56
2023	0.93	0.62	0.56
2024	0.93	0.62	0.56
2025	0.93	0.62	0.56
2026	0.93	0.62	0.56
2027	0.93	0.62	0.56
2028	0.93	0.62	0.56
2029	0.93	0.62	0.56
2030	0.93	0.62	0.56

Table C.35. Residential Lighting Equipment Efficacies (lumens/watt)

Year	CFL	EE Fluor	EE Incan	HID	Std Fluor	Std Incan
2004	55	85	22	85	85	15
2005	55	85	22	85	85	15
2006	55	85	22	85	85	15
2007	55	85	22	85	85	15
2008	55	85	22	85	85	15
2009	55	85	22	85	85	15
2010	60	85	22	85	85	15
2011	60	85	22	85	85	15
2012	60	85	22	85	85	15
2013	60	85	22	85	85	15
2014	60	85	22	85	85	15
2015	60	85	22	85	85	15
2016	60	85	22	85	85	15
2017	60	85	22	85	85	15
2018	60	85	22	85	85	15
2019	60	85	22	85	85	15
2020	60	85	22	85	85	15
2021	60	85	22	85	85	15
2022	60	85	22	85	85	15
2023	60	85	22	85	85	15
2024	60	85	22	85	85	15
2025	60	85	22	85	85	15
2026	60	85	22	85	85	15
2027	60	85	22	85	85	15
2028	60	85	22	85	85	15
2029	60	85	22	85	85	15
2030	60	85	22	85	85	15

C.3.2 Commercial Equipment Efficiencies

Table C.36. Commercial Heating Equipment Efficiencies*

Equipment	Efficiency
Elec FA (AFUE)	1.00
Elec HP (COP)	1.99
Gas HE Furn (AFUE)	0.92
Gas Std Furn (AFUE)	0.80
Oil Furn (AFUE)	0.80
*Efficiencies for commercial heating are constant throughout the analysis period so are not presented by year.	

Table C.37. Commercial Cooling Equipment Efficiencies*

Equipment	Efficiency
Elec CAC (COP)	3.02
Elec Chiller (COP)	4.00
Elec HP (COP)	2.93
Elec Room (COP)	2.64
Gas Chiller (COP)	4.00
*Efficiencies for commercial cooling are constant throughout the analysis period so are not presented by year.	

Table C.38. Commercial Water Heating Equipment Efficiencies

Year	Elec WH	Gas WH	Oil WH
2004	0.85	0.80	0.80
2005	0.85	0.80	0.80
2006	0.86	0.80	0.80
2007	0.86	0.80	0.80
2008	0.86	0.80	0.80
2009	0.86	0.80	0.80
2010	0.86	0.80	0.80
2011	0.86	0.80	0.80
2012	0.86	0.80	0.80
2013	0.86	0.80	0.80
2014	0.86	0.80	0.80
2015	0.86	0.80	0.80
2016	0.86	0.80	0.80
2017	0.86	0.80	0.80
2018	0.86	0.80	0.80
2019	0.86	0.80	0.80
2020	0.86	0.80	0.80
2021	0.86	0.80	0.80
2022	0.86	0.80	0.80
2023	0.86	0.80	0.80
2024	0.86	0.80	0.80
2025	0.86	0.80	0.80
2026	0.86	0.80	0.80
2027	0.86	0.80	0.80
2028	0.86	0.80	0.80
2029	0.86	0.80	0.80
2030	0.86	0.80	0.80

Table C.39. Commercial Lighting Equipment Efficacies (lumens/watt)

Year	CFL	EE Fluor	EE Incan	HID	Std Fluor	Std Incan
2004	55	85	22	85	85	15
2005	55	85	22	85	85	15
2006	55	85	22	85	85	15
2007	55	85	22	85	85	15
2008	55	85	22	85	85	15
2009	55	85	22	85	85	15
2010	60	85	22	85	85	15
2011	60	85	22	85	85	15
2012	60	85	22	85	85	15
2013	60	85	22	85	85	15
2014	60	85	22	85	85	15
2015	60	85	22	85	85	15
2016	60	85	22	85	85	15
2017	60	85	22	85	85	15
2018	60	85	22	85	85	15
2019	60	85	22	85	85	15
2020	60	85	22	85	85	15
2021	60	85	22	85	85	15
2022	60	85	22	85	85	15
2023	60	85	22	85	85	15
2024	60	85	22	85	85	15
2025	60	85	22	85	85	15
2026	60	85	22	85	85	15
2027	60	85	22	85	85	15
2028	60	85	22	85	85	15
2029	60	85	22	85	85	15
2030	60	85	22	85	85	15

C.4 Baseline Equipment Life

Equipment life values are used in calculating the number of units representing the potential target market for projects targeting specific pieces of equipment. Baseline factors are taken from *Appliance Magazine*, NEMS, and the *BTS Core Data Book*. Tables C.40 through C.47 present the baseline equipment life assumptions.

C.4.1 Residential Equipment Life

Table C.40. Residential Heating Equipment Life

Equipment	Life (yr)
Elec FA	20
Elec HP	13
Gas HE Furn	20
Gas HP	13
Gas Std Furn	20
Oil Furn	20

Table C.41. Residential Cooling Equipment Life

Equipment	Life (yr)
Elec CAC	11
Elec HP	13
Elec Room	14
Gas HP	13

Table C.42. Residential Water Heating Equipment Life

Equipment	Life (yr)
Elec WH	10
Gas WH	10
Oil WH	10

Table C.43. Residential Lighting Equipment Life

Equipment	Life (yr)
CFL	10
EE Fluor	10
EE Incan	1
HID	13
Std Fluor	10
Std Incan	1

C.4.2 Commercial Equipment Life

Table C.44. Commercial Heating Equipment Life

Equipment	Life (yr)
Elec FA	20
Elec HP	13
Gas HE Furn	20
Gas Std Furn	20
Oil Furn	20

Table C.45. Commercial Cooling Equipment Life

Equipment	Life (yr)
Elec CAC	11
Elec Chiller	20
Elec HP	13
Elec Room	14
Gas Chiller	20

Table C.46. Commercial Water Heating Equipment Life

Equipment	Life (yr)
Elec WH	10
Gas WH	10
Oil WH	10

Table C.47. Commercial Lighting Equipment Life

Equipment	Life (yr)
CFL	10
EE Fluor	10
EE Incan	1
HID	13
Std Fluor	10
Std Incan	1

C.5 End-Use Loads

End-use loads represent the baseline energy use per square foot (commercial) or per unit (residential) for heating, cooling, water heating, and lighting uses. End-use loads were updated in June 2000 with energy use information derived from FEDS to reflect current energy technology and consumption behavior. Tables C.48 through C.61 present the end-use load assumptions by building sector, building type, vintage, and region.

C.5.1 Residential End-Use Loads

Table C.48. Residential Mobile Home End-Use Loads

Year	Cool (MMBtu/HH)				Heat (MMBtu/HH)				Water Heat (MMBtu/HH)				Light (kWh/HH)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	10.35	33.45	9.18	29.80	112.53	41.51	92.91	32.96	16.65	14.87	16.65	14.87	1837.50	1837.50	1827.42	1827.42
2005	10.32	33.37	9.16	29.73	112.26	41.41	92.68	32.87	16.61	14.84	16.61	14.84	1832.96	1832.96	1822.90	1822.90
2006	10.30	33.28	9.14	29.65	111.98	41.30	92.45	32.79	16.57	14.80	16.57	14.80	1828.43	1828.43	1818.39	1818.39
2007	10.27	33.20	9.12	29.58	111.70	41.20	92.22	32.71	16.53	14.76	16.53	14.76	1823.91	1823.91	1813.90	1813.90
2008	10.25	33.12	9.09	29.51	111.43	41.10	91.99	32.63	16.49	14.73	16.49	14.73	1819.40	1819.40	1809.41	1809.41
2009	10.22	33.04	9.07	29.43	111.15	41.00	91.77	32.55	16.44	14.69	16.44	14.69	1814.90	1814.90	1804.94	1804.94
2010	10.20	32.96	9.05	29.36	110.88	40.90	91.54	32.47	16.40	14.65	16.40	14.65	1810.42	1810.42	1800.48	1800.48
2011	10.17	32.87	9.03	29.29	110.60	40.80	91.31	32.39	16.36	14.62	16.36	14.62	1805.94	1805.94	1796.03	1796.03
2012	10.15	32.79	9.00	29.21	110.33	40.69	91.09	32.31	16.32	14.58	16.32	14.58	1801.48	1801.48	1791.59	1791.59
2013	10.12	32.71	8.98	29.14	110.06	40.59	90.86	32.23	16.28	14.55	16.28	14.55	1797.03	1797.03	1787.16	1787.16
2014	10.10	32.63	8.96	29.07	109.78	40.49	90.64	32.15	16.24	14.51	16.24	14.51	1792.58	1792.58	1782.74	1782.74
2015	10.07	32.55	8.94	29.00	109.51	40.39	90.41	32.07	16.20	14.47	16.20	14.47	1788.15	1788.15	1778.34	1778.34
2016	10.05	32.47	8.91	28.93	109.24	40.29	90.19	31.99	16.16	14.44	16.16	14.44	1783.73	1783.73	1773.94	1773.94
2017	10.02	32.39	8.89	28.86	108.97	40.19	89.97	31.91	16.12	14.40	16.12	14.40	1779.32	1779.32	1769.56	1769.56
2018	10.00	32.31	8.87	28.78	108.70	40.09	89.75	31.83	16.08	14.37	16.08	14.37	1774.92	1774.92	1765.18	1765.18
2019	9.97	32.23	8.85	28.71	108.43	40.00	89.52	31.75	16.04	14.33	16.04	14.33	1770.54	1770.54	1760.82	1760.82
2020	9.95	32.15	8.83	28.64	108.16	39.90	89.30	31.68	16.00	14.30	16.00	14.30	1766.16	1766.16	1756.46	1756.46
2021	9.92	32.07	8.80	28.57	107.90	39.80	89.08	31.60	15.96	14.26	15.96	14.26	1761.79	1761.79	1752.12	1752.12
2022	9.90	31.99	8.78	28.50	107.63	39.70	88.86	31.52	15.92	14.23	15.92	14.23	1757.44	1757.44	1747.79	1747.79
2023	9.87	31.91	8.76	28.43	107.36	39.60	88.64	31.44	15.88	14.19	15.88	14.19	1753.09	1753.09	1743.47	1743.47
2024	9.85	31.83	8.74	28.36	107.10	39.50	88.42	31.36	15.85	14.16	15.85	14.16	1748.76	1748.76	1739.16	1739.16
2025	9.82	31.75	8.72	28.29	106.83	39.41	88.20	31.29	15.81	14.12	15.81	14.12	1744.44	1744.44	1734.86	1734.86
2026	9.80	31.68	8.70	28.22	106.57	39.31	87.99	31.21	15.77	14.09	15.77	14.09	1740.13	1740.13	1730.57	1730.57
2027	9.78	31.60	8.67	28.15	106.31	39.21	87.77	31.13	15.73	14.05	15.73	14.05	1735.82	1735.82	1726.30	1726.30
2028	9.75	31.52	8.65	28.08	106.04	39.11	87.55	31.05	15.69	14.02	15.69	14.02	1731.53	1731.53	1722.03	1722.03
2029	9.73	31.44	8.63	28.01	105.78	39.02	87.33	30.98	15.65	13.98	15.65	13.98	1727.25	1727.25	1717.77	1717.77
2030	9.70	31.36	8.61	27.94	105.52	38.92	87.12	30.90	15.61	13.95	15.61	13.95	1722.98	1722.98	1713.53	1713.53

Table C.49. Residential Multifamily End-Use Loads

Year	Cool (MMBtu/HH)				Heat (MMBtu/HH)				Water Heat (MMBtu/HH)				Light (kWh/HH)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	9.52	24.16	9.57	23.91	20.12	4.64	16.30	3.39	16.76	14.36	16.76	14.36	2312.70	2312.70	2304.61	2304.61
2005	9.50	24.10	9.55	23.85	20.07	4.62	16.26	3.38	16.72	14.32	16.72	14.32	2306.99	2306.99	2298.91	2298.91
2006	9.48	24.04	9.53	23.80	20.02	4.61	16.22	3.37	16.68	14.29	16.68	14.29	2301.28	2301.28	2293.23	2293.23
2007	9.45	23.98	9.50	23.74	19.97	4.60	16.18	3.36	16.64	14.25	16.64	14.25	2295.60	2295.60	2287.56	2287.56
2008	9.43	23.92	9.48	23.68	19.92	4.59	16.14	3.36	16.60	14.22	16.60	14.22	2289.92	2289.92	2281.90	2281.90
2009	9.41	23.86	9.46	23.62	19.87	4.58	16.10	3.35	16.55	14.18	16.55	14.18	2284.26	2284.26	2276.26	2276.26
2010	9.38	23.80	9.43	23.56	19.82	4.57	16.06	3.34	16.51	14.15	16.51	14.15	2278.61	2278.61	2270.64	2270.64
2011	9.36	23.74	9.41	23.50	19.77	4.56	16.02	3.33	16.47	14.11	16.47	14.11	2272.98	2272.98	2265.02	2265.02
2012	9.34	23.68	9.39	23.44	19.72	4.54	15.98	3.32	16.43	14.08	16.43	14.08	2267.36	2267.36	2259.43	2259.43
2013	9.31	23.62	9.36	23.39	19.67	4.53	15.94	3.31	16.39	14.04	16.39	14.04	2261.76	2261.76	2253.84	2253.84
2014	9.29	23.57	9.34	23.33	19.62	4.52	15.91	3.31	16.35	14.01	16.35	14.01	2256.17	2256.17	2248.27	2248.27
2015	9.27	23.51	9.32	23.27	19.57	4.51	15.87	3.30	16.31	13.97	16.31	13.97	2250.59	2250.59	2242.71	2242.71
2016	9.24	23.45	9.29	23.21	19.53	4.50	15.83	3.29	16.27	13.94	16.27	13.94	2245.03	2245.03	2237.17	2237.17
2017	9.22	23.39	9.27	23.16	19.48	4.49	15.79	3.28	16.23	13.90	16.23	13.90	2239.48	2239.48	2231.64	2231.64
2018	9.20	23.33	9.25	23.10	19.43	4.48	15.75	3.27	16.19	13.87	16.19	13.87	2233.94	2233.94	2226.12	2226.12
2019	9.18	23.28	9.22	23.04	19.38	4.47	15.71	3.27	16.15	13.84	16.15	13.84	2228.42	2228.42	2220.62	2220.62
2020	9.15	23.22	9.20	22.99	19.33	4.46	15.67	3.26	16.11	13.80	16.11	13.80	2222.91	2222.91	2215.13	2215.13
2021	9.13	23.16	9.18	22.93	19.29	4.44	15.63	3.25	16.07	13.77	16.07	13.77	2217.42	2217.42	2209.65	2209.65
2022	9.11	23.10	9.16	22.87	19.24	4.43	15.59	3.24	16.03	13.73	16.03	13.73	2211.93	2211.93	2204.19	2204.19
2023	9.09	23.05	9.13	22.82	19.19	4.42	15.55	3.23	15.99	13.70	15.99	13.70	2206.47	2206.47	2198.74	2198.74
2024	9.06	22.99	9.11	22.76	19.14	4.41	15.52	3.22	15.95	13.67	15.95	13.67	2201.01	2201.01	2193.31	2193.31
2025	9.04	22.93	9.09	22.70	19.10	4.40	15.48	3.22	15.91	13.63	15.91	13.63	2195.57	2195.57	2187.88	2187.88
2026	9.02	22.88	9.07	22.65	19.05	4.39	15.44	3.21	15.87	13.60	15.87	13.60	2190.14	2190.14	2182.48	2182.48
2027	9.00	22.82	9.04	22.59	19.00	4.38	15.40	3.20	15.83	13.56	15.83	13.56	2184.73	2184.73	2177.08	2177.08
2028	8.97	22.76	9.02	22.53	18.96	4.37	15.36	3.19	15.79	13.53	15.79	13.53	2179.33	2179.33	2171.70	2171.70
2029	8.95	22.71	9.00	22.48	18.91	4.36	15.33	3.19	15.75	13.50	15.75	13.50	2173.94	2173.94	2166.33	2166.33
2030	8.93	22.65	8.98	22.42	18.86	4.35	15.29	3.18	15.72	13.46	15.72	13.46	2168.57	2168.57	2160.98	2160.98

Table C.50. Residential Single-Family End-Use Loads

Year	Cool (MMBtu/HH)				Heat (MMBtu/HH)				Water Heat (MMBtu/HH)				Light (kWh/HH)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	10.23	33.37	9.77	30.89	67.87	18.17	49.86	11.58	21.93	19.32	21.93	19.32	2882.98	2882.98	2867.15	2867.15
2005	10.21	33.29	9.74	30.81	67.70	18.13	49.73	11.55	21.88	19.27	21.88	19.27	2875.85	2875.85	2860.06	2860.06
2006	10.18	33.20	9.72	30.74	67.54	18.08	49.61	11.52	21.82	19.23	21.82	19.23	2868.74	2868.74	2852.99	2852.99
2007	10.16	33.12	9.70	30.66	67.37	18.04	49.49	11.49	21.77	19.18	21.77	19.18	2861.65	2861.65	2845.94	2845.94
2008	10.13	33.04	9.67	30.59	67.20	17.99	49.36	11.46	21.72	19.13	21.72	19.13	2854.58	2854.58	2838.91	2838.91
2009	10.11	32.96	9.65	30.51	67.04	17.95	49.24	11.43	21.66	19.08	21.66	19.08	2847.52	2847.52	2831.89	2831.89
2010	10.08	32.88	9.62	30.43	66.87	17.91	49.12	11.41	21.61	19.04	21.61	19.04	2840.48	2840.48	2824.89	2824.89
2011	10.06	32.80	9.60	30.36	66.70	17.86	49.00	11.38	21.55	18.99	21.55	18.99	2833.46	2833.46	2817.90	2817.90
2012	10.03	32.71	9.58	30.28	66.54	17.82	48.88	11.35	21.50	18.94	21.50	18.94	2826.45	2826.45	2810.94	2810.94
2013	10.01	32.63	9.55	30.21	66.38	17.77	48.76	11.32	21.45	18.90	21.45	18.90	2819.47	2819.47	2803.99	2803.99
2014	9.98	32.55	9.53	30.13	66.21	17.73	48.64	11.29	21.39	18.85	21.39	18.85	2812.50	2812.50	2797.06	2797.06
2015	9.96	32.47	9.51	30.06	66.05	17.69	48.52	11.27	21.34	18.80	21.34	18.80	2805.55	2805.55	2790.14	2790.14
2016	9.94	32.39	9.48	29.99	65.88	17.64	48.40	11.24	21.29	18.76	21.29	18.76	2798.61	2798.61	2783.25	2783.25
2017	9.91	32.31	9.46	29.91	65.72	17.60	48.28	11.21	21.24	18.71	21.24	18.71	2791.69	2791.69	2776.37	2776.37
2018	9.89	32.23	9.44	29.84	65.56	17.55	48.16	11.18	21.18	18.66	21.18	18.66	2784.79	2784.79	2769.50	2769.50
2019	9.86	32.15	9.41	29.76	65.40	17.51	48.04	11.16	21.13	18.62	21.13	18.62	2777.91	2777.91	2762.66	2762.66
2020	9.84	32.07	9.39	29.69	65.24	17.47	47.92	11.13	21.08	18.57	21.08	18.57	2771.04	2771.04	2755.83	2755.83
2021	9.81	31.99	9.37	29.62	65.07	17.42	47.80	11.10	21.03	18.53	21.03	18.53	2764.19	2764.19	2749.02	2749.02
2022	9.79	31.92	9.34	29.54	64.91	17.38	47.68	11.07	20.98	18.48	20.98	18.48	2757.36	2757.36	2742.22	2742.22
2023	9.76	31.84	9.32	29.47	64.75	17.34	47.57	11.05	20.92	18.43	20.92	18.43	2750.54	2750.54	2735.44	2735.44
2024	9.74	31.76	9.30	29.40	64.59	17.30	47.45	11.02	20.87	18.39	20.87	18.39	2743.74	2743.74	2728.68	2728.68
2025	9.72	31.68	9.27	29.33	64.43	17.25	47.33	10.99	20.82	18.34	20.82	18.34	2736.96	2736.96	2721.94	2721.94
2026	9.69	31.60	9.25	29.25	64.27	17.21	47.21	10.96	20.77	18.30	20.77	18.30	2730.19	2730.19	2715.21	2715.21
2027	9.67	31.52	9.23	29.18	64.11	17.17	47.10	10.94	20.72	18.25	20.72	18.25	2723.45	2723.45	2708.50	2708.50
2028	9.64	31.44	9.21	29.11	63.96	17.13	46.98	10.91	20.67	18.21	20.67	18.21	2716.71	2716.71	2701.80	2701.80
2029	9.62	31.37	9.18	29.04	63.80	17.08	46.86	10.88	20.62	18.16	20.62	18.16	2710.00	2710.00	2695.12	2695.12
2030	9.60	31.29	9.16	28.96	63.64	17.04	46.75	10.86	20.56	18.12	20.56	18.12	2703.30	2703.30	2688.46	2688.46

C.5.2 Commercial End-Use Loads

Table C.51. Commercial Assembly End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (Kbtu/SF)				Light (KWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	14.93	33.65	14.45	31.21	23.35	9.16	15.93	5.46	1.82	1.69	1.87	1.72	4.91	4.81	4.89	4.75
2005	14.89	33.57	14.42	31.13	23.30	9.14	15.90	5.44	1.82	1.68	1.86	1.72	4.90	4.80	4.88	4.74
2006	14.85	33.48	14.38	31.06	23.24	9.12	15.86	5.43	1.81	1.68	1.86	1.72	4.89	4.78	4.87	4.73
2007	14.82	33.40	14.35	30.98	23.18	9.09	15.82	5.41	1.81	1.68	1.85	1.71	4.87	4.77	4.86	4.72
2008	14.78	33.32	14.31	30.90	23.12	9.07	15.78	5.40	1.80	1.67	1.85	1.71	4.86	4.76	4.85	4.71
2009	14.74	33.24	14.28	30.83	23.07	9.05	15.74	5.39	1.80	1.67	1.84	1.70	4.85	4.75	4.83	4.70
2010	14.71	33.15	14.24	30.75	23.01	9.03	15.70	5.37	1.80	1.66	1.84	1.70	4.84	4.74	4.82	4.68
2011	14.67	33.07	14.21	30.67	22.95	9.00	15.66	5.36	1.79	1.66	1.83	1.69	4.83	4.73	4.81	4.67
2012	14.63	32.99	14.17	30.60	22.90	8.98	15.62	5.35	1.79	1.66	1.83	1.69	4.81	4.71	4.80	4.66
2013	14.60	32.91	14.14	30.52	22.84	8.96	15.58	5.34	1.78	1.65	1.82	1.69	4.80	4.70	4.79	4.65
2014	14.56	32.83	14.10	30.45	22.78	8.94	15.55	5.32	1.78	1.65	1.82	1.68	4.79	4.69	4.77	4.64
2015	14.52	32.75	14.07	30.37	22.73	8.91	15.51	5.31	1.77	1.64	1.82	1.68	4.78	4.68	4.76	4.63
2016	14.49	32.67	14.03	30.30	22.67	8.89	15.47	5.30	1.77	1.64	1.81	1.67	4.77	4.67	4.75	4.62
2017	14.45	32.59	14.00	30.22	22.61	8.87	15.43	5.28	1.77	1.63	1.81	1.67	4.75	4.66	4.74	4.60
2018	14.42	32.50	13.96	30.15	22.56	8.85	15.39	5.27	1.76	1.63	1.80	1.67	4.74	4.64	4.73	4.59
2019	14.38	32.42	13.93	30.07	22.50	8.83	15.35	5.26	1.76	1.63	1.80	1.66	4.73	4.63	4.72	4.58
2020	14.35	32.34	13.89	30.00	22.45	8.80	15.32	5.24	1.75	1.62	1.79	1.66	4.72	4.62	4.70	4.57
2021	14.31	32.26	13.86	29.92	22.39	8.78	15.28	5.23	1.75	1.62	1.79	1.65	4.71	4.61	4.69	4.56
2022	14.28	32.18	13.82	29.85	22.34	8.76	15.24	5.22	1.74	1.61	1.78	1.65	4.70	4.60	4.68	4.55
2023	14.24	32.11	13.79	29.78	22.28	8.74	15.20	5.20	1.74	1.61	1.78	1.65	4.68	4.59	4.67	4.54
2024	14.20	32.03	13.76	29.70	22.23	8.72	15.17	5.19	1.73	1.61	1.78	1.64	4.67	4.58	4.66	4.53
2025	14.17	31.95	13.72	29.63	22.17	8.70	15.13	5.18	1.73	1.60	1.77	1.64	4.66	4.56	4.65	4.51
2026	14.13	31.87	13.69	29.56	22.12	8.67	15.09	5.17	1.73	1.60	1.77	1.63	4.65	4.55	4.63	4.50
2027	14.10	31.79	13.65	29.48	22.06	8.65	15.05	5.15	1.72	1.59	1.76	1.63	4.64	4.54	4.62	4.49
2028	14.06	31.71	13.62	29.41	22.01	8.63	15.02	5.14	1.72	1.59	1.76	1.62	4.63	4.53	4.61	4.48
2029	14.03	31.63	13.59	29.34	21.95	8.61	14.98	5.13	1.71	1.59	1.75	1.62	4.62	4.52	4.60	4.47
2030	14.00	31.55	13.55	29.26	21.90	8.59	14.94	5.12	1.71	1.58	1.75	1.62	4.60	4.51	4.59	4.46

Table C.52. Commercial Education End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	14.68	32.28	13.53	29.01	26.98	9.55	18.76	7.16	3.52	3.09	3.54	3.12	3.74	3.75	3.34	3.36
2005	14.64	32.20	13.49	28.94	26.91	9.53	18.71	7.14	3.51	3.09	3.53	3.12	3.73	3.74	3.33	3.35
2006	14.61	32.12	13.46	28.87	26.84	9.50	18.67	7.12	3.50	3.08	3.52	3.11	3.72	3.73	3.33	3.34
2007	14.57	32.04	13.43	28.80	26.78	9.48	18.62	7.11	3.49	3.07	3.51	3.10	3.71	3.73	3.32	3.33
2008	14.54	31.96	13.39	28.73	26.71	9.46	18.57	7.09	3.48	3.06	3.50	3.09	3.71	3.72	3.31	3.33
2009	14.50	31.88	13.36	28.66	26.64	9.43	18.53	7.07	3.47	3.06	3.50	3.09	3.70	3.71	3.30	3.32
2010	14.46	31.80	13.33	28.59	26.58	9.41	18.48	7.05	3.46	3.05	3.49	3.08	3.69	3.70	3.29	3.31
2011	14.43	31.72	13.30	28.52	26.51	9.39	18.44	7.04	3.46	3.04	3.48	3.07	3.68	3.69	3.29	3.30
2012	14.39	31.64	13.26	28.45	26.45	9.36	18.39	7.02	3.45	3.03	3.47	3.06	3.67	3.68	3.28	3.29
2013	14.36	31.56	13.23	28.38	26.38	9.34	18.35	7.00	3.44	3.03	3.46	3.06	3.66	3.67	3.27	3.29
2014	14.32	31.49	13.20	28.31	26.32	9.32	18.30	6.98	3.43	3.02	3.45	3.05	3.65	3.66	3.26	3.28
2015	14.29	31.41	13.16	28.24	26.25	9.29	18.26	6.97	3.42	3.01	3.44	3.04	3.64	3.65	3.25	3.27
2016	14.25	31.33	13.13	28.17	26.19	9.27	18.21	6.95	3.41	3.00	3.44	3.03	3.63	3.64	3.24	3.26
2017	14.22	31.25	13.10	28.10	26.12	9.25	18.17	6.93	3.40	3.00	3.43	3.03	3.62	3.63	3.24	3.25
2018	14.18	31.18	13.07	28.03	26.06	9.22	18.12	6.91	3.40	2.99	3.42	3.02	3.61	3.63	3.23	3.25
2019	14.14	31.10	13.03	27.96	25.99	9.20	18.08	6.90	3.39	2.98	3.41	3.01	3.61	3.62	3.22	3.24
2020	14.11	31.02	13.00	27.89	25.93	9.18	18.03	6.88	3.38	2.97	3.40	3.00	3.60	3.61	3.21	3.23
2021	14.08	30.95	12.97	27.82	25.86	9.16	17.99	6.86	3.37	2.97	3.39	3.00	3.59	3.60	3.20	3.22
2022	14.04	30.87	12.94	27.75	25.80	9.13	17.94	6.85	3.36	2.96	3.39	2.99	3.58	3.59	3.20	3.21
2023	14.01	30.79	12.91	27.68	25.74	9.11	17.90	6.83	3.35	2.95	3.38	2.98	3.57	3.58	3.19	3.21
2024	13.97	30.72	12.87	27.61	25.67	9.09	17.85	6.81	3.35	2.95	3.37	2.97	3.56	3.57	3.18	3.20
2025	13.94	30.64	12.84	27.54	25.61	9.07	17.81	6.80	3.34	2.94	3.36	2.97	3.55	3.56	3.17	3.19
2026	13.90	30.57	12.81	27.48	25.55	9.04	17.77	6.78	3.33	2.93	3.35	2.96	3.54	3.55	3.17	3.18
2027	13.87	30.49	12.78	27.41	25.48	9.02	17.72	6.76	3.32	2.92	3.34	2.95	3.54	3.55	3.16	3.17
2028	13.83	30.41	12.75	27.34	25.42	9.00	17.68	6.75	3.31	2.92	3.34	2.94	3.53	3.54	3.15	3.17
2029	13.80	30.34	12.72	27.27	25.36	8.98	17.63	6.73	3.30	2.91	3.33	2.94	3.52	3.53	3.14	3.16
2030	13.77	30.26	12.68	27.21	25.29	8.95	17.59	6.71	3.30	2.90	3.32	2.93	3.51	3.52	3.13	3.15

Table C.53. Commercial Food Sales End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	38.85	78.59	40.11	75.47	21.68	4.21	10.74	1.36	4.05	4.68	4.13	10.04	12.80	12.80	11.92	11.92
2005	38.75	78.40	40.01	75.28	21.63	4.20	10.71	1.36	4.04	4.67	4.12	10.02	12.77	12.77	11.89	11.89
2006	38.65	78.20	39.91	75.09	21.57	4.19	10.69	1.35	4.03	4.66	4.11	9.99	12.74	12.74	11.86	11.86
2007	38.56	78.01	39.81	74.91	21.52	4.18	10.66	1.35	4.02	4.64	4.10	9.97	12.71	12.71	11.83	11.83
2008	38.46	77.82	39.71	74.72	21.47	4.17	10.63	1.35	4.01	4.63	4.09	9.94	12.68	12.68	11.80	11.80
2009	38.37	77.63	39.62	74.54	21.41	4.16	10.61	1.34	4.00	4.62	4.08	9.92	12.64	12.65	11.77	11.77
2010	38.27	77.43	39.52	74.35	21.36	4.15	10.58	1.34	3.99	4.61	4.07	9.90	12.61	12.61	11.74	11.74
2011	38.18	77.24	39.42	74.17	21.31	4.14	10.55	1.34	3.98	4.60	4.06	9.87	12.58	12.58	11.71	11.71
2012	38.08	77.05	39.32	73.99	21.25	4.13	10.53	1.33	3.97	4.59	4.05	9.85	12.55	12.55	11.69	11.69
2013	37.99	76.86	39.23	73.80	21.20	4.12	10.50	1.33	3.96	4.58	4.04	9.82	12.52	12.52	11.66	11.66
2014	37.90	76.67	39.13	73.62	21.15	4.11	10.48	1.33	3.95	4.56	4.03	9.80	12.49	12.49	11.63	11.63
2015	37.80	76.48	39.03	73.44	21.10	4.10	10.45	1.32	3.94	4.55	4.02	9.77	12.46	12.46	11.60	11.60
2016	37.71	76.29	38.94	73.26	21.05	4.09	10.43	1.32	3.93	4.54	4.01	9.75	12.43	12.43	11.57	11.57
2017	37.62	76.10	38.84	73.08	20.99	4.08	10.40	1.32	3.92	4.53	4.00	9.73	12.40	12.40	11.54	11.54
2018	37.52	75.92	38.74	72.90	20.94	4.07	10.37	1.31	3.91	4.52	3.99	9.70	12.37	12.37	11.51	11.51
2019	37.43	75.73	38.65	72.72	20.89	4.06	10.35	1.31	3.90	4.51	3.98	9.68	12.34	12.34	11.49	11.49
2020	37.34	75.54	38.55	72.54	20.84	4.05	10.32	1.31	3.89	4.50	3.97	9.65	12.30	12.31	11.46	11.46
2021	37.25	75.35	38.46	72.36	20.79	4.04	10.30	1.30	3.88	4.49	3.96	9.63	12.27	12.28	11.43	11.43
2022	37.15	75.17	38.36	72.18	20.73	4.03	10.27	1.30	3.87	4.47	3.95	9.61	12.24	12.25	11.40	11.40
2023	37.06	74.98	38.27	72.00	20.68	4.02	10.25	1.30	3.86	4.46	3.94	9.58	12.21	12.22	11.37	11.37
2024	36.97	74.80	38.17	71.82	20.63	4.01	10.22	1.29	3.85	4.45	3.93	9.56	12.18	12.19	11.34	11.34
2025	36.88	74.61	38.08	71.64	20.58	4.00	10.20	1.29	3.84	4.44	3.92	9.53	12.15	12.16	11.32	11.32
2026	36.79	74.43	37.98	71.47	20.53	3.99	10.17	1.29	3.83	4.43	3.91	9.51	12.12	12.13	11.29	11.29
2027	36.70	74.24	37.89	71.29	20.48	3.98	10.15	1.28	3.82	4.42	3.90	9.49	12.09	12.10	11.26	11.26
2028	36.61	74.06	37.80	71.11	20.43	3.97	10.12	1.28	3.81	4.41	3.89	9.46	12.06	12.07	11.23	11.23
2029	36.52	73.88	37.70	70.94	20.38	3.96	10.09	1.28	3.80	4.40	3.88	9.44	12.03	12.04	11.20	11.20
2030	36.43	73.69	37.61	70.76	20.33	3.95	10.07	1.28	3.80	4.39	3.87	9.42	12.00	12.01	11.18	11.18

Table C.54. Commercial Food Service End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	47.51	93.35	51.34	91.38	22.03	6.07	8.17	2.52	10.02	9.05	10.08	9.10	9.29	9.29	9.29	9.29
2005	47.39	93.12	51.22	91.15	21.97	6.05	8.15	2.51	9.99	9.03	10.05	9.08	9.27	9.27	9.27	9.27
2006	47.28	92.89	51.09	90.92	21.92	6.04	8.13	2.51	9.97	9.01	10.03	9.06	9.24	9.24	9.24	9.24
2007	47.16	92.66	50.96	90.70	21.86	6.02	8.11	2.50	9.94	8.99	10.00	9.04	9.22	9.22	9.22	9.22
2008	47.04	92.43	50.84	90.48	21.81	6.01	8.09	2.50	9.92	8.96	9.98	9.01	9.20	9.20	9.20	9.20
2009	46.93	92.20	50.71	90.25	21.76	5.99	8.07	2.49	9.90	8.94	9.95	8.99	9.18	9.18	9.18	9.18
2010	46.81	91.97	50.59	90.03	21.70	5.98	8.05	2.48	9.87	8.92	9.93	8.97	9.15	9.15	9.15	9.15
2011	46.69	91.75	50.46	89.81	21.65	5.96	8.03	2.48	9.85	8.90	9.90	8.95	9.13	9.13	9.13	9.13
2012	46.58	91.52	50.34	89.58	21.59	5.95	8.01	2.47	9.82	8.88	9.88	8.92	9.11	9.11	9.11	9.11
2013	46.46	91.29	50.21	89.36	21.54	5.93	7.99	2.46	9.80	8.85	9.86	8.90	9.09	9.09	9.09	9.09
2014	46.35	91.07	50.09	89.14	21.49	5.92	7.97	2.46	9.77	8.83	9.83	8.88	9.06	9.06	9.06	9.06
2015	46.23	90.84	49.96	88.92	21.43	5.90	7.95	2.45	9.75	8.81	9.81	8.86	9.04	9.04	9.04	9.04
2016	46.12	90.62	49.84	88.70	21.38	5.89	7.93	2.45	9.73	8.79	9.78	8.84	9.02	9.02	9.02	9.02
2017	46.01	90.39	49.72	88.48	21.33	5.87	7.91	2.44	9.70	8.77	9.76	8.81	9.00	9.00	9.00	9.00
2018	45.89	90.17	49.59	88.26	21.28	5.86	7.89	2.43	9.68	8.75	9.73	8.79	8.97	8.97	8.97	8.97
2019	45.78	89.95	49.47	88.05	21.22	5.85	7.87	2.43	9.65	8.72	9.71	8.77	8.95	8.95	8.95	8.95
2020	45.67	89.72	49.35	87.83	21.17	5.83	7.85	2.42	9.63	8.70	9.69	8.75	8.93	8.93	8.93	8.93
2021	45.55	89.50	49.23	87.61	21.12	5.82	7.83	2.42	9.61	8.68	9.66	8.73	8.91	8.91	8.91	8.91
2022	45.44	89.28	49.11	87.39	21.07	5.80	7.81	2.41	9.58	8.66	9.64	8.71	8.89	8.89	8.89	8.89
2023	45.33	89.06	48.98	87.18	21.01	5.79	7.79	2.40	9.56	8.64	9.62	8.68	8.86	8.86	8.86	8.86
2024	45.22	88.84	48.86	86.96	20.96	5.77	7.77	2.40	9.53	8.62	9.59	8.66	8.84	8.84	8.84	8.84
2025	45.10	88.62	48.74	86.75	20.91	5.76	7.75	2.39	9.51	8.60	9.57	8.64	8.82	8.82	8.82	8.82
2026	44.99	88.40	48.62	86.53	20.86	5.74	7.73	2.39	9.49	8.57	9.54	8.62	8.80	8.80	8.80	8.80
2027	44.88	88.18	48.50	86.32	20.81	5.73	7.71	2.38	9.46	8.55	9.52	8.60	8.78	8.78	8.78	8.78
2028	44.77	87.97	48.38	86.11	20.76	5.72	7.70	2.37	9.44	8.53	9.50	8.58	8.75	8.75	8.75	8.75
2029	44.66	87.75	48.26	85.89	20.70	5.70	7.68	2.37	9.42	8.51	9.47	8.56	8.73	8.73	8.73	8.73
2030	44.55	87.53	48.14	85.68	20.65	5.69	7.66	2.36	0.00	0.00	0.00	0.00	8.71	8.71	8.71	8.71

Table C.55. Commercial Health Care End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	45.20	92.71	41.25	87.40	8.47	2.94	6.91	1.08	34.09	31.13	34.58	31.54	14.57	14.51	13.01	12.94
2005	45.09	92.48	41.14	87.19	8.45	2.94	6.90	1.08	34.01	31.05	34.49	31.47	14.53	14.48	12.98	12.91
2006	44.98	92.25	41.04	86.97	8.43	2.93	6.88	1.08	33.93	30.97	34.41	31.39	14.49	14.44	12.94	12.88
2007	44.86	92.03	40.94	86.76	8.41	2.92	6.86	1.08	33.84	30.90	34.32	31.31	14.46	14.41	12.91	12.85
2008	44.75	91.80	40.84	86.54	8.39	2.91	6.85	1.07	33.76	30.82	34.24	31.23	14.42	14.37	12.88	12.81
2009	44.64	91.57	40.74	86.33	8.37	2.91	6.83	1.07	33.68	30.74	34.15	31.16	14.39	14.34	12.85	12.78
2010	44.53	91.35	40.64	86.11	8.35	2.90	6.81	1.07	33.59	30.67	34.07	31.08	14.35	14.30	12.82	12.75
2011	44.42	91.12	40.54	85.90	8.33	2.89	6.80	1.07	33.51	30.59	33.98	31.00	14.31	14.26	12.79	12.72
2012	44.31	90.89	40.44	85.69	8.30	2.89	6.78	1.06	33.43	30.52	33.90	30.93	14.28	14.23	12.75	12.69
2013	44.20	90.67	40.34	85.48	8.28	2.88	6.76	1.06	33.34	30.44	33.82	30.85	14.24	14.19	12.72	12.66
2014	44.09	90.45	40.24	85.27	8.26	2.87	6.75	1.06	33.26	30.37	33.73	30.77	14.21	14.16	12.69	12.63
2015	43.98	90.22	40.14	85.06	8.24	2.86	6.73	1.06	33.18	30.29	33.65	30.70	14.17	14.12	12.66	12.59
2016	43.88	90.00	40.04	84.84	8.22	2.86	6.71	1.05	33.10	30.22	33.57	30.62	14.14	14.09	12.63	12.56
2017	43.77	89.78	39.94	84.64	8.20	2.85	6.70	1.05	33.02	30.14	33.48	30.55	14.10	14.05	12.60	12.53
2018	43.66	89.55	39.84	84.43	8.18	2.84	6.68	1.05	32.93	30.07	33.40	30.47	14.07	14.02	12.57	12.50
2019	43.55	89.33	39.74	84.22	8.16	2.84	6.66	1.05	32.85	29.99	33.32	30.40	14.03	13.99	12.53	12.47
2020	43.44	89.11	39.64	84.01	8.14	2.83	6.65	1.04	32.77	29.92	33.24	30.32	14.00	13.95	12.50	12.44
2021	43.34	88.89	39.55	83.80	8.12	2.82	6.63	1.04	32.69	29.85	33.15	30.25	13.96	13.92	12.47	12.41
2022	43.23	88.67	39.45	83.59	8.10	2.82	6.61	1.04	32.61	29.77	33.07	30.17	13.93	13.88	12.44	12.38
2023	43.12	88.45	39.35	83.39	8.08	2.81	6.60	1.03	32.53	29.70	32.99	30.10	13.90	13.85	12.41	12.35
2024	43.02	88.23	39.25	83.18	8.06	2.80	6.58	1.03	32.45	29.62	32.91	30.02	13.86	13.81	12.38	12.32
2025	42.91	88.02	39.16	82.98	8.04	2.79	6.56	1.03	32.37	29.55	32.83	29.95	13.83	13.78	12.35	12.29
2026	42.80	87.80	39.06	82.77	8.02	2.79	6.55	1.03	32.29	29.48	32.75	29.87	13.79	13.75	12.32	12.26
2027	42.70	87.58	38.96	82.57	8.00	2.78	6.53	1.02	32.21	29.41	32.66	29.80	13.76	13.71	12.29	12.23
2028	42.59	87.37	38.87	82.36	7.98	2.77	6.52	1.02	32.13	29.33	32.58	29.73	13.73	13.68	12.26	12.20
2029	42.49	87.15	38.77	82.16	7.96	2.77	6.50	1.02	32.05	29.26	32.50	29.65	13.69	13.64	12.23	12.17
2030	42.38	86.93	38.68	81.96	7.94	2.76	6.48	1.02	31.97	29.19	32.42	29.58	13.66	13.61	12.20	12.14

Table C.56. Commercial Lodging End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	12.83	27.27	11.40	24.81	11.59	3.09	10.64	1.47	12.48	12.10	12.73	12.31	3.20	3.21	2.91	2.91
2005	12.80	27.21	11.38	24.74	11.56	3.08	10.62	1.46	12.45	12.07	12.69	12.28	3.20	3.20	2.91	2.90
2006	12.77	27.14	11.35	24.68	11.53	3.07	10.59	1.46	12.42	12.04	12.66	12.25	3.19	3.19	2.90	2.89
2007	12.74	27.07	11.32	24.62	11.51	3.07	10.56	1.46	12.39	12.01	12.63	12.22	3.18	3.19	2.89	2.89
2008	12.71	27.00	11.29	24.56	11.48	3.06	10.54	1.45	12.36	11.98	12.60	12.19	3.17	3.18	2.89	2.88
2009	12.68	26.94	11.26	24.50	11.45	3.05	10.51	1.45	12.33	11.95	12.57	12.16	3.16	3.17	2.88	2.87
2010	12.64	26.87	11.24	24.44	11.42	3.04	10.49	1.45	12.30	11.92	12.54	12.13	3.16	3.16	2.87	2.86
2011	12.61	26.80	11.21	24.38	11.39	3.04	10.46	1.44	12.27	11.89	12.51	12.10	3.15	3.16	2.86	2.86
2012	12.58	26.74	11.18	24.32	11.36	3.03	10.43	1.44	12.24	11.86	12.48	12.07	3.14	3.15	2.86	2.85
2013	12.55	26.67	11.15	24.26	11.34	3.02	10.41	1.43	12.21	11.83	12.45	12.04	3.13	3.14	2.85	2.84
2014	12.52	26.61	11.12	24.20	11.31	3.01	10.38	1.43	12.18	11.80	12.41	12.01	3.12	3.13	2.84	2.84
2015	12.49	26.54	11.10	24.14	11.28	3.01	10.36	1.43	12.15	11.77	12.38	11.98	3.12	3.12	2.84	2.83
2016	12.46	26.48	11.07	24.08	11.25	3.00	10.33	1.42	12.12	11.74	12.35	11.95	3.11	3.12	2.83	2.82
2017	12.43	26.41	11.04	24.02	11.22	2.99	10.31	1.42	12.09	11.71	12.32	11.92	3.10	3.11	2.82	2.82
2018	12.40	26.34	11.02	23.96	11.20	2.98	10.28	1.42	12.06	11.69	12.29	11.89	3.09	3.10	2.82	2.81
2019	12.37	26.28	10.99	23.90	11.17	2.98	10.26	1.41	12.03	11.66	12.26	11.86	3.09	3.09	2.81	2.80
2020	12.34	26.21	10.96	23.84	11.14	2.97	10.23	1.41	12.00	11.63	12.23	11.83	3.08	3.09	2.80	2.79
2021	12.30	26.15	10.93	23.78	11.11	2.96	10.20	1.41	11.97	11.60	12.20	11.80	3.07	3.08	2.79	2.79
2022	12.27	26.08	10.91	23.72	11.09	2.95	10.18	1.40	11.94	11.57	12.17	11.77	3.06	3.07	2.79	2.78
2023	12.24	26.02	10.88	23.67	11.06	2.95	10.15	1.40	11.91	11.54	12.14	11.74	3.06	3.06	2.78	2.77
2024	12.21	25.96	10.85	23.61	11.03	2.94	10.13	1.40	11.88	11.51	12.11	11.71	3.05	3.06	2.77	2.77
2025	12.18	25.89	10.83	23.55	11.00	2.93	10.10	1.39	11.85	11.48	12.08	11.68	3.04	3.05	2.77	2.76
2026	12.15	25.83	10.80	23.49	10.98	2.92	10.08	1.39	11.82	11.46	12.05	11.66	3.03	3.04	2.76	2.75
2027	12.12	25.76	10.77	23.43	10.95	2.92	10.05	1.39	11.79	11.43	12.02	11.63	3.03	3.03	2.75	2.75
2028	12.09	25.70	10.75	23.38	10.92	2.91	10.03	1.38	11.76	11.40	11.99	11.60	3.02	3.03	2.75	2.74
2029	12.06	25.64	10.72	23.32	10.90	2.90	10.00	1.38	11.74	11.37	11.96	11.57	3.01	3.02	2.74	2.73
2030	12.03	25.57	10.69	23.26	10.87	2.90	9.98	1.38	11.71	11.34	11.93	11.54	3.00	3.01	2.73	2.73

Table C.57. Commercial Mercantile/Service End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	20.09	43.96	19.82	41.91	24.60	6.46	15.68	4.44	0.85	0.79	0.87	0.81	10.24	10.22	9.49	9.51
2005	20.04	43.85	19.77	41.81	24.54	6.44	15.65	4.43	0.85	0.79	0.87	0.81	10.21	10.20	9.46	9.48
2006	19.99	43.75	19.72	41.71	24.48	6.43	15.61	4.42	0.84	0.79	0.87	0.81	10.19	10.17	9.44	9.46
2007	19.94	43.64	19.67	41.60	24.42	6.41	15.57	4.41	0.84	0.79	0.87	0.81	10.16	10.14	9.41	9.44
2008	19.89	43.53	19.62	41.50	24.36	6.39	15.53	4.40	0.84	0.78	0.87	0.81	10.14	10.12	9.39	9.41
2009	19.84	43.42	19.58	41.40	24.30	6.38	15.49	4.39	0.84	0.78	0.86	0.80	10.11	10.09	9.37	9.39
2010	19.79	43.32	19.53	41.30	24.24	6.36	15.45	4.37	0.84	0.78	0.86	0.80	10.09	10.07	9.35	9.37
2011	19.74	43.21	19.48	41.19	24.18	6.35	15.42	4.36	0.83	0.78	0.86	0.80	10.06	10.04	9.32	9.34
2012	19.69	43.10	19.43	41.09	24.12	6.33	15.38	4.35	0.83	0.78	0.86	0.80	10.04	10.02	9.30	9.32
2013	19.64	43.00	19.38	40.99	24.06	6.32	15.34	4.34	0.83	0.78	0.86	0.80	10.01	10.00	9.28	9.30
2014	19.60	42.89	19.34	40.89	24.00	6.30	15.30	4.33	0.83	0.77	0.85	0.79	9.99	9.97	9.25	9.28
2015	19.55	42.78	19.29	40.79	23.94	6.28	15.26	4.32	0.83	0.77	0.85	0.79	9.96	9.95	9.23	9.25
2016	19.50	42.68	19.24	40.69	23.88	6.27	15.23	4.31	0.82	0.77	0.85	0.79	9.94	9.92	9.21	9.23
2017	19.45	42.57	19.19	40.59	23.82	6.25	15.19	4.30	0.82	0.77	0.85	0.79	9.91	9.90	9.18	9.21
2018	19.40	42.47	19.14	40.49	23.76	6.24	15.15	4.29	0.82	0.77	0.85	0.79	9.89	9.87	9.16	9.18
2019	19.36	42.36	19.10	40.39	23.70	6.22	15.11	4.28	0.82	0.76	0.84	0.78	9.86	9.85	9.14	9.16
2020	19.31	42.26	19.05	40.29	23.64	6.21	15.08	4.27	0.82	0.76	0.84	0.78	9.84	9.82	9.12	9.14
2021	19.26	42.15	19.00	40.19	23.59	6.19	15.04	4.26	0.81	0.76	0.84	0.78	9.82	9.80	9.09	9.12
2022	19.21	42.05	18.96	40.09	23.53	6.18	15.00	4.25	0.81	0.76	0.84	0.78	9.79	9.78	9.07	9.09
2023	19.16	41.94	18.91	39.99	23.47	6.16	14.96	4.24	0.81	0.76	0.83	0.78	9.77	9.75	9.05	9.07
2024	19.12	41.84	18.86	39.89	23.41	6.15	14.93	4.23	0.81	0.75	0.83	0.78	9.74	9.73	9.03	9.05
2025	19.07	41.74	18.82	39.79	23.35	6.13	14.89	4.22	0.81	0.75	0.83	0.77	9.72	9.70	9.00	9.03
2026	19.02	41.63	18.77	39.69	23.30	6.12	14.85	4.21	0.80	0.75	0.83	0.77	9.70	9.68	8.98	9.00
2027	18.98	41.53	18.72	39.59	23.24	6.10	14.82	4.19	0.80	0.75	0.83	0.77	9.67	9.65	8.96	8.98
2028	18.93	41.43	18.68	39.50	23.18	6.09	14.78	4.18	0.80	0.75	0.82	0.77	9.65	9.63	8.94	8.96
2029	18.88	41.33	18.63	39.40	23.12	6.07	14.74	4.17	0.80	0.75	0.82	0.77	9.62	9.61	8.92	8.94
2030	18.84	41.22	18.58	39.30	23.07	6.06	14.71	4.16	0.80	0.74	0.82	0.76	9.60	9.58	8.89	8.92

Table C.58. Commercial Office-Large End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	24.49	38.82	21.60	35.11	24.73	13.94	23.22	10.08	0.60	0.56	0.62	0.57	5.65	5.64	4.73	4.72
2005	24.43	38.73	21.55	35.02	24.67	13.90	23.16	10.05	0.60	0.56	0.62	0.57	5.63	5.63	4.72	4.71
2006	24.37	38.63	21.49	34.94	24.61	13.87	23.10	10.03	0.60	0.56	0.62	0.57	5.62	5.62	4.71	4.70
2007	24.31	38.54	21.44	34.85	24.55	13.83	23.05	10.00	0.60	0.56	0.61	0.57	5.60	5.60	4.70	4.69
2008	24.25	38.44	21.39	34.77	24.49	13.80	22.99	9.98	0.60	0.55	0.61	0.56	5.59	5.59	4.69	4.68
2009	24.19	38.35	21.33	34.68	24.42	13.77	22.93	9.95	0.60	0.55	0.61	0.56	5.58	5.57	4.68	4.67
2010	24.13	38.25	21.28	34.59	24.36	13.73	22.88	9.93	0.59	0.55	0.61	0.56	5.56	5.56	4.67	4.65
2011	24.07	38.16	21.23	34.51	24.30	13.70	22.82	9.90	0.59	0.55	0.61	0.56	5.55	5.55	4.65	4.64
2012	24.01	38.06	21.18	34.42	24.24	13.66	22.76	9.88	0.59	0.55	0.61	0.56	5.54	5.53	4.64	4.63
2013	23.95	37.97	21.12	34.34	24.18	13.63	22.71	9.85	0.59	0.55	0.60	0.56	5.52	5.52	4.63	4.62
2014	23.89	37.87	21.07	34.25	24.12	13.60	22.65	9.83	0.59	0.55	0.60	0.56	5.51	5.50	4.62	4.61
2015	23.84	37.78	21.02	34.17	24.06	13.56	22.60	9.80	0.59	0.54	0.60	0.55	5.49	5.49	4.61	4.60
2016	23.78	37.69	20.97	34.08	24.01	13.53	22.54	9.78	0.59	0.54	0.60	0.55	5.48	5.48	4.60	4.59
2017	23.72	37.59	20.91	34.00	23.95	13.50	22.48	9.76	0.58	0.54	0.60	0.55	5.47	5.46	4.58	4.57
2018	23.66	37.50	20.86	33.92	23.89	13.46	22.43	9.73	0.58	0.54	0.60	0.55	5.45	5.45	4.57	4.56
2019	23.60	37.41	20.81	33.83	23.83	13.43	22.37	9.71	0.58	0.54	0.60	0.55	5.44	5.44	4.56	4.55
2020	23.54	37.32	20.76	33.75	23.77	13.40	22.32	9.68	0.58	0.54	0.59	0.55	5.43	5.42	4.55	4.54
2021	23.48	37.22	20.71	33.66	23.71	13.36	22.26	9.66	0.58	0.54	0.59	0.55	5.41	5.41	4.54	4.53
2022	23.43	37.13	20.66	33.58	23.65	13.33	22.21	9.64	0.58	0.54	0.59	0.54	5.40	5.40	4.53	4.52
2023	23.37	37.04	20.61	33.50	23.59	13.30	22.15	9.61	0.58	0.53	0.59	0.54	5.39	5.38	4.52	4.51
2024	23.31	36.95	20.56	33.42	23.53	13.26	22.10	9.59	0.57	0.53	0.59	0.54	5.37	5.37	4.51	4.50
2025	23.25	36.86	20.50	33.33	23.48	13.23	22.04	9.56	0.57	0.53	0.59	0.54	5.36	5.36	4.50	4.49
2026	23.20	36.77	20.45	33.25	23.42	13.20	21.99	9.54	0.57	0.53	0.59	0.54	5.35	5.34	4.48	4.47
2027	23.14	36.68	20.40	33.17	23.36	13.17	21.93	9.52	0.57	0.53	0.58	0.54	5.33	5.33	4.47	4.46
2028	23.08	36.58	20.35	33.09	23.30	13.13	21.88	9.49	0.57	0.53	0.58	0.54	5.32	5.32	4.46	4.45
2029	23.02	36.49	20.30	33.00	23.25	13.10	21.83	9.47	0.57	0.53	0.58	0.54	5.31	5.30	4.45	4.44
2030	22.97	36.40	20.25	32.92	23.19	13.07	21.77	9.45	0.57	0.52	0.58	0.53	5.29	5.29	4.44	4.43

Table C.59. Commercial Office-Small End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	22.12	39.10	18.01	32.73	19.78	7.36	20.47	5.18	0.72	0.68	0.74	0.69	5.95	5.86	5.02	4.92
2005	22.07	39.00	17.97	32.64	19.73	7.34	20.42	5.17	0.72	0.68	0.73	0.69	5.93	5.85	5.00	4.91
2006	22.01	38.90	17.93	32.56	19.68	7.32	20.37	5.15	0.72	0.68	0.73	0.69	5.92	5.83	4.99	4.90
2007	21.96	38.81	17.88	32.48	19.64	7.30	20.32	5.14	0.72	0.68	0.73	0.69	5.90	5.82	4.98	4.89
2008	21.90	38.71	17.84	32.40	19.59	7.29	20.27	5.13	0.72	0.67	0.73	0.68	5.89	5.80	4.97	4.87
2009	21.85	38.61	17.79	32.32	19.54	7.27	20.22	5.12	0.72	0.67	0.73	0.68	5.87	5.79	4.96	4.86
2010	21.80	38.52	17.75	32.24	19.49	7.25	20.17	5.10	0.71	0.67	0.73	0.68	5.86	5.78	4.94	4.85
2011	21.74	38.42	17.70	32.16	19.44	7.23	20.12	5.09	0.71	0.67	0.72	0.68	5.84	5.76	4.93	4.84
2012	21.69	38.33	17.66	32.08	19.39	7.21	20.07	5.08	0.71	0.67	0.72	0.68	5.83	5.75	4.92	4.83
2013	21.63	38.23	17.62	32.00	19.35	7.20	20.02	5.07	0.71	0.67	0.72	0.68	5.82	5.73	4.91	4.81
2014	21.58	38.14	17.57	31.93	19.30	7.18	19.97	5.05	0.71	0.67	0.72	0.67	5.80	5.72	4.89	4.80
2015	21.53	38.05	17.53	31.85	19.25	7.16	19.92	5.04	0.71	0.66	0.72	0.67	5.79	5.70	4.88	4.79
2016	21.47	37.95	17.49	31.77	19.20	7.14	19.87	5.03	0.70	0.66	0.71	0.67	5.77	5.69	4.87	4.78
2017	21.42	37.86	17.44	31.69	19.16	7.13	19.82	5.02	0.70	0.66	0.71	0.67	5.76	5.68	4.86	4.77
2018	21.37	37.76	17.40	31.61	19.11	7.11	19.77	5.00	0.70	0.66	0.71	0.67	5.74	5.66	4.85	4.75
2019	21.32	37.67	17.36	31.53	19.06	7.09	19.72	4.99	0.70	0.66	0.71	0.67	5.73	5.65	4.83	4.74
2020	21.26	37.58	17.31	31.45	19.01	7.07	19.68	4.98	0.70	0.66	0.71	0.66	5.72	5.63	4.82	4.73
2021	21.21	37.48	17.27	31.38	18.97	7.05	19.63	4.97	0.69	0.65	0.71	0.66	5.70	5.62	4.81	4.72
2022	21.16	37.39	17.23	31.30	18.92	7.04	19.58	4.95	0.69	0.65	0.70	0.66	5.69	5.61	4.80	4.71
2023	21.11	37.30	17.19	31.22	18.87	7.02	19.53	4.94	0.69	0.65	0.70	0.66	5.67	5.59	4.79	4.70
2024	21.05	37.21	17.14	31.15	18.83	7.00	19.48	4.93	0.69	0.65	0.70	0.66	5.66	5.58	4.77	4.68
2025	21.00	37.12	17.10	31.07	18.78	6.99	19.43	4.92	0.69	0.65	0.70	0.66	5.65	5.57	4.76	4.67
2026	20.95	37.02	17.06	30.99	18.73	6.97	19.39	4.91	0.69	0.65	0.70	0.65	5.63	5.55	4.75	4.66
2027	20.90	36.93	17.02	30.91	18.69	6.95	19.34	4.89	0.68	0.64	0.70	0.65	5.62	5.54	4.74	4.65
2028	20.85	36.84	16.98	30.84	18.64	6.93	19.29	4.88	0.68	0.64	0.69	0.65	5.60	5.52	4.73	4.64
2029	20.79	36.75	16.93	30.76	18.59	6.92	19.24	4.87	0.68	0.64	0.69	0.65	5.59	5.51	4.72	4.63
2030	20.74	36.66	16.89	30.69	18.55	6.90	19.19	4.86	0.68	0.64	0.69	0.65	5.58	5.50	4.70	4.62

Table C.60. Commercial Other End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	5.55	19.03	5.97	17.20	29.84	7.97	17.24	3.94	0.34	0.33	0.35	0.34	4.52	4.51	4.35	4.38
2005	5.54	18.98	5.96	17.16	29.76	7.95	17.19	3.93	0.34	0.33	0.35	0.34	4.51	4.50	4.34	4.37
2006	5.53	18.93	5.94	17.12	29.69	7.93	17.15	3.92	0.34	0.33	0.35	0.34	4.49	4.49	4.33	4.36
2007	5.51	18.88	5.93	17.07	29.61	7.91	17.11	3.91	0.34	0.33	0.35	0.34	4.48	4.48	4.32	4.35
2008	5.50	18.84	5.91	17.03	29.54	7.89	17.07	3.90	0.34	0.32	0.35	0.34	4.47	4.47	4.31	4.34
2009	5.49	18.79	5.90	16.99	29.47	7.88	17.02	3.89	0.33	0.32	0.35	0.33	4.46	4.46	4.30	4.33
2010	5.47	18.74	5.88	16.95	29.40	7.86	16.98	3.88	0.33	0.32	0.35	0.33	4.45	4.45	4.29	4.32
2011	5.46	18.70	5.87	16.91	29.32	7.84	16.94	3.87	0.33	0.32	0.35	0.33	4.44	4.44	4.28	4.31
2012	5.45	18.65	5.85	16.86	29.25	7.82	16.90	3.86	0.33	0.32	0.35	0.33	4.43	4.43	4.27	4.30
2013	5.43	18.61	5.84	16.82	29.18	7.80	16.86	3.85	0.33	0.32	0.34	0.33	4.42	4.41	4.26	4.29
2014	5.42	18.56	5.82	16.78	29.11	7.78	16.82	3.84	0.33	0.32	0.34	0.33	4.41	4.40	4.25	4.28
2015	5.41	18.51	5.81	16.74	29.03	7.76	16.77	3.83	0.33	0.32	0.34	0.33	4.40	4.39	4.24	4.27
2016	5.39	18.47	5.80	16.70	28.96	7.74	16.73	3.82	0.33	0.32	0.34	0.33	4.38	4.38	4.23	4.26
2017	5.38	18.42	5.78	16.66	28.89	7.72	16.69	3.81	0.33	0.32	0.34	0.33	4.37	4.37	4.22	4.25
2018	5.37	18.38	5.77	16.62	28.82	7.70	16.65	3.80	0.33	0.32	0.34	0.33	4.36	4.36	4.20	4.24
2019	5.35	18.33	5.75	16.57	28.75	7.68	16.61	3.79	0.33	0.32	0.34	0.33	4.35	4.35	4.19	4.22
2020	5.34	18.29	5.74	16.53	28.68	7.66	16.57	3.78	0.33	0.32	0.34	0.33	4.34	4.34	4.18	4.21
2021	5.33	18.24	5.72	16.49	28.61	7.64	16.53	3.77	0.32	0.31	0.34	0.33	4.33	4.33	4.17	4.20
2022	5.31	18.20	5.71	16.45	28.54	7.63	16.49	3.76	0.32	0.31	0.34	0.32	4.32	4.32	4.16	4.19
2023	5.30	18.15	5.70	16.41	28.46	7.61	16.44	3.76	0.32	0.31	0.34	0.32	4.31	4.31	4.15	4.18
2024	5.29	18.11	5.68	16.37	28.39	7.59	16.40	3.75	0.32	0.31	0.34	0.32	4.30	4.30	4.14	4.17
2025	5.27	18.06	5.67	16.33	28.32	7.57	16.36	3.74	0.32	0.31	0.33	0.32	4.29	4.29	4.13	4.16
2026	5.26	18.02	5.65	16.29	28.25	7.55	16.32	3.73	0.32	0.31	0.33	0.32	4.28	4.28	4.12	4.15
2027	5.25	17.97	5.64	16.25	28.18	7.53	16.28	3.72	0.32	0.31	0.33	0.32	4.27	4.26	4.11	4.14
2028	5.23	17.93	5.63	16.21	28.11	7.51	16.24	3.71	0.32	0.31	0.33	0.32	4.26	4.25	4.10	4.13
2029	5.22	17.88	5.61	16.17	28.05	7.49	16.20	3.70	0.32	0.31	0.33	0.32	4.25	4.24	4.09	4.12
2030	5.21	17.84	5.60	16.13	27.98	7.48	16.16	3.69	0.32	0.31	0.33	0.32	4.24	4.23	4.08	4.11

Table C.61. Commercial Warehouse End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	0.18	6.88	0.14	3.60	24.55	6.56	12.21	1.63	0.23	0.24	0.25	0.25	2.50	2.50	2.44	2.44
2005	0.18	6.87	0.14	3.59	24.49	6.54	12.18	1.63	0.23	0.23	0.25	0.25	2.50	2.50	2.43	2.43
2006	0.18	6.85	0.14	3.58	24.43	6.52	12.15	1.63	0.23	0.23	0.25	0.25	2.49	2.49	2.43	2.43
2007	0.18	6.83	0.14	3.57	24.37	6.51	12.12	1.62	0.23	0.23	0.25	0.24	2.48	2.49	2.42	2.42
2008	0.18	6.82	0.14	3.56	24.31	6.49	12.09	1.62	0.23	0.23	0.24	0.24	2.48	2.48	2.41	2.42
2009	0.18	6.80	0.14	3.55	24.25	6.48	12.06	1.61	0.23	0.23	0.24	0.24	2.47	2.47	2.41	2.41
2010	0.18	6.78	0.14	3.54	24.19	6.46	12.03	1.61	0.23	0.23	0.24	0.24	2.47	2.47	2.40	2.40
2011	0.18	6.77	0.13	3.53	24.13	6.44	12.00	1.61	0.23	0.23	0.24	0.24	2.46	2.46	2.40	2.40
2012	0.18	6.75	0.13	3.52	24.07	6.43	11.97	1.60	0.23	0.23	0.24	0.24	2.45	2.45	2.39	2.39
2013	0.18	6.73	0.13	3.52	24.01	6.41	11.94	1.60	0.23	0.23	0.24	0.24	2.45	2.45	2.38	2.39
2014	0.18	6.72	0.13	3.51	23.95	6.40	11.91	1.59	0.23	0.23	0.24	0.24	2.44	2.44	2.38	2.38
2015	0.18	6.70	0.13	3.50	23.90	6.38	11.88	1.59	0.23	0.23	0.24	0.24	2.44	2.44	2.37	2.37
2016	0.18	6.68	0.13	3.49	23.84	6.37	11.85	1.59	0.23	0.23	0.24	0.24	2.43	2.43	2.37	2.37
2017	0.18	6.67	0.13	3.48	23.78	6.35	11.82	1.58	0.23	0.23	0.24	0.24	2.42	2.42	2.36	2.36
2018	0.18	6.65	0.13	3.47	23.72	6.33	11.79	1.58	0.23	0.23	0.24	0.24	2.42	2.42	2.35	2.36
2019	0.18	6.63	0.13	3.46	23.66	6.32	11.76	1.57	0.23	0.23	0.24	0.24	2.41	2.41	2.35	2.35
2020	0.18	6.62	0.13	3.46	23.60	6.30	11.73	1.57	0.22	0.23	0.24	0.24	2.41	2.41	2.34	2.34
2021	0.18	6.60	0.13	3.45	23.54	6.29	11.71	1.57	0.22	0.23	0.24	0.24	2.40	2.40	2.34	2.34
2022	0.18	6.58	0.13	3.44	23.48	6.27	11.68	1.56	0.22	0.23	0.24	0.24	2.39	2.39	2.33	2.33
2023	0.18	6.57	0.13	3.43	23.43	6.26	11.65	1.56	0.22	0.22	0.24	0.23	2.39	2.39	2.33	2.33
2024	0.17	6.55	0.13	3.42	23.37	6.24	11.62	1.56	0.22	0.22	0.24	0.23	2.38	2.38	2.32	2.32
2025	0.17	6.54	0.13	3.41	23.31	6.22	11.59	1.55	0.22	0.22	0.23	0.23	2.38	2.38	2.31	2.32
2026	0.17	6.52	0.13	3.40	23.25	6.21	11.56	1.55	0.22	0.22	0.23	0.23	2.37	2.37	2.31	2.31
2027	0.17	6.50	0.13	3.40	23.20	6.19	11.53	1.54	0.22	0.22	0.23	0.23	2.36	2.37	2.30	2.30
2028	0.17	6.49	0.13	3.39	23.14	6.18	11.50	1.54	0.22	0.22	0.23	0.23	2.36	2.36	2.30	2.30
2029	0.17	6.47	0.13	3.38	23.08	6.16	11.48	1.54	0.22	0.22	0.23	0.23	2.35	2.35	2.29	2.29
2030	0.17	6.46	0.13	3.37	23.02	6.15	11.45	1.53	0.22	0.22	0.23	0.23	2.35	2.35	2.29	2.29

C.6 Lighting Interactions Factors

Changes in lighting impact the heating and cooling loads of a building because lights also produce heat. These interactions are accounted for through the development and use of lighting interaction factors.

C.6.1 Case Definition—Baseline

Baseline consumption in all buildings is the same as the baseline load data presented in Tables C.48 through C.61. Baseline loads were determined using NEMSFEDS, an iteration tool based on FEDS that allows a single case to be modified and run (loads only) by altering inputs to a [casename].ini file. In this manner a single case can be used to run a multi-dimensional matrix of all combinations of building type, size, vintage, location, occupancy, and lighting configurations. Statistical data of actual building size and vintage information were then used to combine the NEMSFEDS results into a location by building type results matrix where each building type is of the weighted average size and weighted average vintage (for existing) or 2000 vintage for new buildings.

Values were determined for all combinations of the following:

- Commercial, residential, and industrial building types
- New and existing buildings
- Nine census regions (and north and south for BESET).

C.6.2 Case Definition—Variation from Baseline

Lighting loads were decreased from 100% to 0% with 10% steps. As a result of the decrease in lighting loads, the heating load increased and the cooling load decreased. The percentage increases in the heating load and percentage decreases in the cooling load were then determined at each of the steps. Lastly, the results were converted via regression to equations (one for heat and one for cooling for each combination of building type, new/existing, and location) where the only input is the percentage reduction in the lighting load. The regression equations are of the form:

Heat $\Delta heat = a * \Delta L^b$

Cool $\Delta cool = c * \Delta L^2 + d * \Delta L$

Where:
a, b, c, & *d* are coefficients (presented in Tables C.62 through C.65)
Δheat = the fractional change in heating load
Δcool = the fractional change in cooling load
ΔL = the percentage reduction in lighting load

C.6.3 Specification

Because of the way this was modeled the implicit assumption is that a 20% penetration rate means that 20% of the lighting within all buildings of a certain type, vintage, and region get the BT/WIP technology. Hence the 20% value can be used directly. The alternative, which could also be easily modeled using the data generated in this activity, is that 20% of the buildings within a certain type, vintage, and region have 100% of the BT/WIP technology. This would require that a weighted average be developed (20% with 100% penetration and 80% with 0% penetration). For the time being we will ignore the later approach and focus on the former.

C.6.4 Caveats/Constraints

Application of the lighting interaction factors need to have an absolute limit on the heating and cooling load impacts. For example, an XX% increase in heating load (based on the equations) translates to YY MMBtu/yr; however, we know that the change in the heating load cannot exceed the lighting load change. Hence, the actual load impacts (heating and cooling) are programmed as the minimum of 1) the change in the lighting load and 2) the change in the heating load as determined by the product of the percentage reduction (from the regression equation) and the unadjusted heating. This same constraint must be applied to the cooling as well.

Tables C.62 through C.65 present the lighting interaction factors. Note that the coefficients contained in the tables reference the equations presented above.

Table C.62. Residential Heat Lighting Interaction Factors

Building Type	Vintage	Region	Coefficient a	Coefficient b
Mobile Home	Existing	North	0.0004270	1.0037380
Mobile Home	Existing	South	0.0008340	1.0096560
Mobile Home	New	North	0.0005060	1.0044900
Mobile Home	New	South	0.0010170	1.0109510
Multi Family	Existing	North	0.0021250	1.0226010
Multi Family	Existing	South	0.0046220	1.1273510
Multi Family	New	North	0.0024560	1.0280980
Multi Family	New	South	0.0044600	1.2090270
Single Family	Existing	North	0.0009330	1.0110920
Single Family	Existing	South	0.0023330	1.0375540
Single Family	New	North	0.0011870	1.0139700
Single Family	New	South	0.0032970	1.0707780

Table C.63. Residential Cool Lighting Interaction Factors

Building Type	Vintage	Region	Coefficient c	Coefficient d
Mobile Home	Existing	North	0.0000002	-0.0006579
Mobile Home	Existing	South	0.0000002	-0.0005977
Mobile Home	New	North	0.0000002	-0.0007648
Mobile Home	New	South	0.0000002	-0.0006953
Multi Family	Existing	North	0.0000016	-0.0021230
Multi Family	Existing	South	0.0000011	-0.0018487
Multi Family	New	North	0.0000014	-0.0022249
Multi Family	New	South	0.0000013	-0.0019758
Single Family	Existing	North	0.0000008	-0.0016490
Single Family	Existing	South	0.0000005	-0.0013311
Single Family	New	North	0.0000012	-0.0019544
Single Family	New	South	0.0000007	-0.0015623

Table C.64. Commercial Heat Lighting Interaction Factors

Building Type	Vintage	Region	Coefficient a	Coefficient b
Assembly	Existing	North	0.0021350	1.0425220
Assembly	Existing	South	0.0027620	1.0671970
Assembly	New	North	0.0023980	1.0471820
Assembly	New	South	0.0033980	1.0884520
Education	Existing	North	0.0025850	1.0533410
Education	Existing	South	0.0036940	1.1028510
Education	New	North	0.0030640	1.0560240
Education	New	South	0.0037390	1.1107990
Food Sales	Existing	North	0.0080300	1.1614610
Food Sales	Existing	South	0.0048320	1.5397610
Food Sales	New	North	0.0136250	1.1885550
Food Sales	New	South	0.0107590	1.4628680
Food Service	Existing	North	0.0045980	1.1173690
Food Service	Existing	South	0.0055760	1.2109920
Food Service	New	North	0.0066790	1.1608490
Food Service	New	South	0.0048350	1.6300790
Health Care	Existing	North	0.0099260	1.1141170
Health Care	Existing	South	0.0104810	1.2452230
Health Care	New	North	0.0099180	1.1152260
Health Care	New	South	0.0051680	1.9017270
Lodging	Existing	North	0.0051560	1.0452890
Lodging	Existing	South	0.0062920	1.2579540
Lodging	New	North	0.0048340	1.0343510
Lodging	New	South	0.0043410	1.5146920

Building Type	Vintage	Region	Coefficient a	Coefficient b
Merc/Service	Existing	North	0.0076920	1.1300060
Merc/Service	Existing	South	0.0039690	1.5529340
Merc/Service	New	North	0.0106140	1.1696480
Merc/Service	New	South	0.0041970	1.5951010
Office-Large	Existing	North	0.0017950	1.0256950
Office-Large	Existing	South	0.0020350	1.0394010
Office-Large	New	North	0.0015750	1.0226400
Office-Large	New	South	0.0022050	1.0464980
Office-Small	Existing	North	0.0025640	1.0360660
Office-Small	Existing	South	0.0034230	1.0698730
Office-Small	New	North	0.0020530	1.0284990
Office-Small	New	South	0.0039030	1.0860080
Other	Existing	North	0.0031740	1.0475370
Other	Existing	South	0.0029860	1.3700020
Other	New	North	0.0049840	1.0779460
Other	New	South	0.0046370	1.4307770
Warehouse	Existing	North	0.0024270	1.0346750
Warehouse	Existing	South	0.0030460	1.0856270
Warehouse	New	North	0.0047010	1.0770960
Warehouse	New	South	0.0070410	1.2944710

Table C.65. Commercial Cool Lighting Interaction Factors

Building Type	Vintage	Region	Coefficient c	Coefficient d
Assembly	Existing	North	0.0000112	-0.0067194
Assembly	Existing	South	0.0000033	-0.0047299
Assembly	New	North	0.0000123	-0.0071985
Assembly	New	South	0.0000040	-0.0051491
Education	Existing	North	0.0000067	-0.0050878
Education	Existing	South	0.0000026	-0.0037712
Education	New	North	0.0000068	-0.0054184
Education	New	South	0.0000032	-0.0039730
Food Sales	Existing	North	0.0000130	-0.0072780
Food Sales	Existing	South	0.0000057	-0.0055939
Food Sales	New	North	0.0000133	-0.0072755
Food Sales	New	South	0.0000064	-0.0057319
Food Service	Existing	North	0.0000050	-0.0046340
Food Service	Existing	South	0.0000015	-0.0034510
Food Service	New	North	0.0000052	-0.0048961
Food Service	New	South	0.0000013	-0.0036404
Health Care	Existing	North	0.0000101	-0.0062786
Health Care	Existing	South	0.0000008	-0.0046037
Health Care	New	North	0.0000070	-0.0055847
Health Care	New	South	-0.0000012	-0.0041603
Lodging	Existing	North	0.0000047	-0.0045271
Lodging	Existing	South	0.0000034	-0.0036586
Lodging	New	North	0.0000056	-0.0047403
Lodging	New	South	0.0000020	-0.0037478
Merc/Service	Existing	North	0.0000247	-0.0102030
Merc/Service	Existing	South	0.0000136	-0.0080290
Merc/Service	New	North	0.0000266	-0.0106650
Merc/Service	New	South	0.0000150	-0.0083544
Office-Large	Existing	North	0.0000014	-0.0049673
Office-Large	Existing	South	0.0000008	-0.0036900
Office-Large	New	North	0.0000011	-0.0044716
Office-Large	New	South	0.0000006	-0.0033358
Office-Small	Existing	North	0.0000042	-0.0052292
Office-Small	Existing	South	0.0000016	-0.0038771
Office-Small	New	North	0.0000043	-0.0051372
Office-Small	New	South	0.0000014	-0.0037777
Other	Existing	North	0.0000183	-0.0093593
Other	Existing	South	0.0000136	-0.0066405
Other	New	North	0.0000230	-0.0105200
Other	New	South	0.0000162	-0.0077043

Building Type	Vintage	Region	Coefficient c	Coefficient d
Warehouse	Existing	North	0.0000748	-0.0155040
Warehouse	Existing	South	0.0000450	-0.0105220
Warehouse	New	North	0.0001406	-0.0235170
Warehouse	New	South	0.0001005	-0.0180370

C.7 Emissions Coefficients

Tables C.66 through C.68 present the emissions coefficients used in the FY04 GPRA analysis to compute the emissions reductions. Emissions coefficients were provided by PBFA (EERE 2002, Appendix B).

Table C.66. Electricity Emissions Coefficients
(MMton/TBtu delivered)

Year	Carbon	SO2	Nox	VOCs	PM	CO
2004	0.056751	0.000643	0.000471	0.000009	0.000013	0.000072
2005	0.058195	0.000723	0.000500	0.000006	0.000016	0.000068
2006	0.057528	0.000789	0.000504	0.000006	0.000015	0.000062
2007	0.059937	0.000912	0.000539	0.000006	0.000018	0.000056
2008	0.058014	0.000885	0.000524	0.000006	0.000018	0.000054
2009	0.056075	0.000857	0.000509	0.000005	0.000018	0.000052
2010	0.054119	0.000830	0.000494	0.000005	0.000018	0.000050
2011	0.052904	0.000800	0.000481	0.000005	0.000018	0.000050
2012	0.051699	0.000770	0.000468	0.000005	0.000017	0.000050
2013	0.050505	0.000742	0.000456	0.000005	0.000016	0.000049
2014	0.049321	0.000713	0.000443	0.000005	0.000015	0.000049
2015	0.048148	0.000685	0.000431	0.000005	0.000015	0.000048
2016	0.047500	0.000669	0.000424	0.000005	0.000014	0.000048
2017	0.046855	0.000653	0.000418	0.000005	0.000014	0.000049
2018	0.046215	0.000637	0.000411	0.000005	0.000014	0.000049
2019	0.045579	0.000621	0.000404	0.000005	0.000014	0.000049
2020	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2021	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2022	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2023	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2024	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2025	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2026	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2027	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2028	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2029	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2030	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049

Table C.67. Natural Gas Emissions Coefficients
(MMton/TBtu delivered)

Emission	Coefficient
Carbon	0.014400
SO2	0.000000
Nox	0.000106
VOCs	0.000003
PM	0.000000
CO	0.000029

Table C.68. Fuel Oil Emissions Coefficients
(MMton/TBtu delivered)

Emission	Coefficient
Carbon	0.019750
SO2	0.000527
Nox	0.000140
VOCs	0.000004
PM	0.000007
CO	0.000013

C.8 Fuel Prices

Tables C.69 through C.70 present the fuel prices used in the FY04 GPRA analysis to calculate the consumer cost (energy cost) savings. Fuel prices were provided by PBFA (EERE 2002, Appendix B).

Table C.69. Residential Fuel Prices (1999 $/MMBtu)

Year	Electricity	Natural Gas	Fuel Oil
2004	22.33	6.65	7.33
2005	21.90	6.63	7.33
2006	22.07	6.61	7.26
2007	21.90	6.60	7.36
2008	21.89	6.58	7.41
2009	21.89	6.55	7.46
2010	21.88	6.53	7.51
2011	21.91	6.51	7.57
2012	21.93	6.49	7.63
2013	21.96	6.48	7.68
2014	21.98	6.46	7.74
2015	22.01	6.44	7.80
2016	22.04	6.46	7.84
2017	22.07	6.48	7.87
2018	22.11	6.51	7.91
2019	22.14	6.53	7.94
2020	22.17	6.55	7.98
2021	22.20	6.55	8.03
2022	22.23	6.55	8.08
2023	22.26	6.56	8.13
2024	22.29	6.56	8.18
2025	22.32	6.56	8.23
2026	22.35	6.56	8.28
2027	22.38	6.56	8.33
2028	22.41	6.57	8.39
2029	22.44	6.57	8.44
2030	22.47	6.57	8.49

Table C.70. Commercial Fuel Prices (1999 $/MMBtu)

Year	Electricity	Natural Gas	Fuel Oil
2004	20.38	5.27	5.12
2005	19.58	5.31	5.12
2006	19.07	5.35	5.05
2007	18.40	5.40	5.14
2008	18.14	5.43	5.19
2009	17.89	5.47	5.23
2010	17.63	5.50	5.28
2011	17.65	5.50	5.33
2012	17.67	5.50	5.39
2013	17.68	5.50	5.44
2014	17.70	5.50	5.50
2015	17.72	5.50	5.55
2016	17.80	5.54	5.59
2017	17.88	5.58	5.63
2018	17.96	5.63	5.67
2019	18.04	5.67	5.71
2020	18.12	5.71	5.75
2021	18.17	5.73	5.80
2022	18.22	5.75	5.85
2023	18.26	5.77	5.90
2024	18.31	5.79	5.95
2025	18.36	5.81	6.00
2026	18.41	5.83	6.05
2027	18.46	5.85	6.11
2028	18.52	5.88	6.16
2029	18.57	5.90	6.22
2030	18.62	5.92	6.27

C.9 Electricity Conversion Factors

Table C.71 presents the marginal heat rates for primary and delivered electricity, and the resulting electricity conversion factors which were used in the FY 2004 GPRA analysis to convert delivered (site) electricity to primary electricity. Heat rates were provided by PBFA (EERE 2002, Appendix B).

Table C.71. Heat Rates and Resulting Electricity Conversion Factors(1)

Year	Heat Rate	Delivered Electric Heat Rate	Electricity Conversion Factor
2004	10713	3413	3.14
2005	10593	3413	3.10
2006	10126	3413	2.97
2007	10102	3413	2.96
2008	9741	3413	2.85
2009	9380	3413	2.75
2010	9019	3413	2.64
2011	8868	3413	2.60
2012	8718	3413	2.55
2013	8567	3413	2.51
2014	8417	3413	2.47
2015	8266	3413	2.42
2016	8191	3413	2.40
2017	8116	3413	2.38
2018	8041	3413	2.36
2019	7966	3413	2.33
2020	7891	3413	2.31
2021	7891	3413	2.31
2022	7891	3413	2.31
2023	7891	3413	2.31
2024	7891	3413	2.31
2025	7891	3413	2.31
2026	7891	3413	2.31
2027	7891	3413	2.31
2028	7891	3413	2.31
2029	7891	3413	2.31
2030	7891	3413	2.31

(1) Heat rates for 2008-2009, 2011-2014, 2016-2019, 2021-2024, and 2026-2029 extrapolated linearly.

Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs

FY 2004 Budget Request

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

(Appendix C Only)

Prepared by the

National Renewable Energy Laboratory

April 2004 NREL/TP-620-36404

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

GPRA 2004 Quality Metrics
Methodology and Results

OFFICE OF INDUSTRIAL TECHNOLOGIES

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Washington, DC

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Table of Contents

1. Overview 1
2. QM Methodology and Results 3
   a. R&D Planning Units 3
      i. Aluminum Industry Vision 4
      ii. Chemicals Industry Vision 6
      iii. Forest Products Industry Vision 9
      iv. Glass Industry Vision 11
      v. Metal Casting Industry Vision 13
      vi. Steel Industry Vision 16
      vii. Mining Industry Vision 19
      viii. Petroleum Refining Industry Vision 20
      ix. Industrial Materials Crosscut 22
      x. Sensors and Controls Crosscut 25
      xi. Combustion Crosscut 26
   b. Technical and Financial Assistance Planning Units 28
      i. Industrial Assessment Center (IAC) Program 28
      ii. Best Practices Program 30

Appendix A - 2004 Quality Metrics Final Summary Tables A1
Appendix B - Technology Impact Projections Model B1

I. Overview

This report describes the results, calculations, and assumptions underlying the GPRA 2004 Quality Metrics results for all Planning Units within the Office of Industrial Technologies.

GPRA 2004 supports planning activities including the FY 2004 Budget Cycle. The Quality Metrics results essentially depict the future impacts on energy, energy costs, and the environment of EERE's FY 2004 programs assuming their logical continuation. The impacts of pre-FY 2004 program funding are therefore not included in GPRA 2004. With this said, however, the known FY 2003 program portfolio is used in GPRA 2004 as a proxy for the as yet unknown content of the actual FY 2004 EERE portfolio. It is assumed that the FY 2004 portfolio will not be so different than the FY 2003 portfolio that its benefits will vary substantially.

In the results of GPRA 2004, total OIT program energy savings for 2010 were 0.956 quads, which for comparison represents 2.4% of baseline industrial energy consumption in 2010. Year 2020 energy savings were 3.934 quads, or 9.1% of 2020 baseline industrial energy consumption. Projected energy savings in 2030 reached 8.547 quads, or 7.5% of extrapolated baseline industrial energy consumption in 2030. The results are summarized in Table 1 below; details are provided in a set of tables included as *Appendix A*.

Comparison with results of the previous GPRA study is complicated by subsequent organizational changes within EERE that have resulted in the removal of the Black Liquor Gasification program and Bio-based Products, NICE^{3,} and Inventions & Innovations planning units from the Office of Industrial Technologies. This report compares the GPRA 2004 results with the previous GPRA 2003 results in two ways: (1) directly, ignoring the fact that large program components were removed between the two studies, and (2) more meaningfully, for only those program components that were considered in both GPRA studies. Both comparisons are documented in *Appendix A*.

In direct comparison with the previous GPRA study, the year-2010 savings were 33% smaller than the 1.417 quads projected in GPRA 2003. Year 2020 savings were 9.4% smaller than the 4.341 quads projected in GPRA 2003. Year-2030 savings were 58% smaller than the GPRA 2003 projection of 8.546 quads. Thus the net study result in GPRA 2004 of several programmatic and many individual analytical changes was a substantial decrease in the 2010 impacts of the OIT programs, a small decrease in mid-term 2020 impacts, and a large decline in longer-term 2030 impacts. These changes are primarily the results of:

- major re-organization of EERE resulting in the removal of the Black Liquor Gasification program and Bio-based Products, NICE^{3,} and Inventions & Innovations planning units from the Office of Industrial Technologies, in addition to the normal evolving portfolio changes in the remaining planning units; and
- methodological changes: (1) in accord with EERE Performance Planning Guidance for the FY 2004-2008 Budget Cycle GPRA 2004 benefits are defined as only the accelerated benefits that would not have occurred without OIT's involvement, and (2) the market penetration curve used in the OIT Impact Projections Model was refined in a way that reduced early-year technology penetrations for many technologies.

Focusing specifically on only those OIT program components remaining after the EERE reorganization shows a more directly comparable pattern of changes. The program components that have been removed from OIT had in GPRA 2003 contributed 0.453 quad to 2010 energy savings, 1.662 quads to 2020 energy savings, and 3.746 quads to 2030 savings. Subtracting these quantities – in effect considering only those

planning units included in both GPRA 2003 and GPRA 2004 -- total OIT year-2010 savings in GPRA 2004 were nearly identical (964 Tbtu in GPRA 2003 cf. 956 Tbtu in GPRA 2004); year-2020 savings were 1,256 Tbtu higher in GPRA 2004; and year-2030 savings were 1,186 Tbtu lower. Thus – as compared to the equivalent GPRA 2003 results – GPRA 2004 benefits were respectively 1% smaller for 2010, 47% higher for 2020, and 25% lower for 2030.

Seventy-nine percent of the net increases from the previous GPRA study in terms of 2020 energy savings were found in two planning elements – Best Practices (949 Tbtu cf.. 438 Tbtu) and Combustion (586 Tbtu cf. 106 Tbtu). The increase in Best Practices in based on a report by D. Jones, et. al., Oak Ridge National Laboratory, "Preliminary Estimation of Energy Management Metrics of the Best Practices Program," May 2002, with additional OIT staff assumptions. The increase in Combustion was due to correction of an order-of-magnitude error in capacity factor for the Super Boiler project. Additional, much smaller increases in year-2020 benefits were seen in Steel (61 Tbtu), Petroleum Refining (53 Tbtu), Mining (38 Tbtu), and Metal Casting (26 Tbtu).

The number of individual Impact Projections Model runs performed in support of OIT's GPRA 2004 study was 199. For comparison, GPRA 2003 was based upon 274 model runs; however, Black Liquor Gasification, Bio-based Products, NICE[3,] and Inventions & Innovations accounted for 47 runs in GPRA 2003. Additionally, a change in the Forest Products planning unit study methodology for GPRA 2004 in effect combined 37 projects into 13 aggregated model runs. Subtracting these differences makes the comparable number of projects accounted for by the GPRA 2004 study as compared to GPRA 2003 approximately equal (199 cf. 203).

In the GPRA 2004 version of the model, additional emphasis was placed upon identifying project milestones leading to commercial introduction, leading many analysts to assume later commercial introduction years than in last year's study. Probably to counter the tendency towards reduced benefits driven by this and other GPRA 2004 methodological changes cited previously, nearly all analysts (Mining is an exception) tended to choose faster market penetration curves to characterize their technologies. Thus, planning unit portfolios characterized by mostly "c" market penetration curves in GPRA 2003 have trended toward mostly "b" curves in GPRA 2004. This pattern, repeated over nearly all planning units, is responsible for a significant part of the increase in year-2020 benefits, and reflects a level of subjectivity inherent in the GPRA methodology. Each project analysis is based upon limited technical, economic, and market characterization data, and a major market driver – the selection from among four possible market penetration curve slopes – is subject to the analyst's judgement.

Table 1. Office of Industrial Technologies - GPRA 2004 QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	192	956	2,340	3,934	4,241	3,615
2. Baseline Industrial Energy Use[1] (TBtu)	37,530	39,420	41,310	43,390	45,600	47,930
3. Primary Energy Savings as Percent of Baseline (%)	0.5	2.4	5.7	9.1	9.3	7.5
4. Energy Cost Savings (B$)	1.04	5.04	11.3	17.9	20.1	18.8
5. Carbon Reduction (MMTCE)	3.38	17.4	41.5	67.9	71.6	59.8

[1]DOE/EIA, *Annual Energy Outlook 2002*, Reference Case Forecast (years 2025 and 2030 extrapolated from 2010-2020 growth trend).

II. QM Methodology and Results

A. *R&D Planning Units*

GPRA Quality Metrics were projected for individual projects within Planning Units and summed to total results for Planning Units and for OIT as a whole. This prospective assessment was carried out with the aid of an experience-based market penetration model designed to estimate the national energy, economic, and environmental impacts of innovative industrial technologies. Model runs for individual R&D projects receiving R&D support were aggregated to obtain energy savings, value of energy saved, and emission reductions associated with each R&D Planning Unit. In aggregating the savings, market targets were examined explicitly to avoid double-counting the same potential savings in the infrequent instances when the same energy efficiency market is clearly addressed by multiple projects. Where possible market overlaps were found, the markets were either assigned to one technology only or divided among the competing technologies under development. This process increases confidence that any systemic double-counting within planning units has been minimized. Nevertheless, some double counting across Planning Units within OIT or with other EERE programs is assumed to remain. The market penetration model used for the analysis is described in *Appendix B*, which includes a blank copy of the model output and the instructions provided for the model's use.

Estimates of the energy savings are based upon information provided to the analysts through the proposal review and contracting process that includes industry participation and review, followed up by program review of these estimates. OIT analysis by sector has focused on assessing where energy is actually consumed and to understand current and best practices for each proposed technology. The participation by industry experts in this process has been critical to helping refine the estimates.

The approximate portion of the fiscal-year 2003 budget represented by the analysis for each Planning Unit was noted but the results were not scaled to 100 percent of the FY 2003 budget. Typically, the projects analyzed represented 75 to 95 percent of the FY 2003 budget for the various Planning Units (see *Appendix A*). Projected benefits for these Planning Units do not include the effects of R&D projects completed prior to the current year. These impacts are significant and are tracked by Pacific Northwest National Laboratory in a series of surveys of equipment providers and users, most recently reported in *Office of Industrial Technologies: Summary of Program Results, 2001.*

The justification for assuming that all of the projects analyzed will succeed is two-fold. First, projects which fail are assumed to be replaced with new projects using different technical approaches to achieve similar goals, so that in the long run, the basic goals will be met by the program, assumed to be continuously funded. Second, the projects analyzed do not comprise 100 percent of the FY 2003 budget, which in itself discounts the aggregated results, equivalent to incorporating some risk of failure into the overall process. In addition, the knowledge benefits of OIT's R&D portfolio are not assessed here; this scientific and technical knowledge can help to underpin additional production technology innovations in the future.

A limited-distribution, four-volume set of notebooks containing all Impact Projections Model runs supporting the GPRA 2004 process is entitled, "GPRA 2004 Quality Metrics: Supporting Spreadsheets." This set of notebooks provides over 1,400 pages of supporting documentation for the R&D project analyses which form the primary basis for the GPRA 2004 results.

1. Aluminum Industry Vision

Table 2. Aluminum Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (Trillion Btu)	0.7	22	101	199	172	144
2. Energy Cost Savings (Billion $)	0.002	0.09	0.46	1.01	0.92	0.80
3. Carbon Reduction (MMTCE)	0.01	0.55	2.65	5.25	4.24	3.21

The GPRA submission for the Aluminum Vision is based on analysis of 23 technologies related to enhancing the energy efficiency, productivity, and environmental performance of aluminum production (both primary and secondary) and fabrication (see table below). The Aluminum Team's FY 2003 budget is approximately $8.1 million. The projects listed below represent approximately 80% of the budget, compared to the 90% figure for the 21 projects analyzed for the GPRA 2002 submission.

Table 3. Summary of Project Runs – Aluminum Industry Vision

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Primary Aluminum Production	Inert Metal Anode	0.94	19.19	2008/b
	Potlining Additives	0.87	3.47	2005/b
	Intelligent Potroom Operation	0.10	0.40	2005/b
	Low-T Wetted Cathode Cell	3.72	55.57	2007/b
	Carbothermic Reduction	1.42	10.01	2007/c
Secondary Aluminum Production	High-Efficiency, Low-Dross Combustion System	0.08	0.98	2006/b
	Reduced Oxidative Melt Loss	1.47	11.22	2005/b
	Energy Eff Isothermal Melting	1.63	13.89	2006/b
	Energy Efficiency in Al Melting	2.02	13.22	2006/b
	Gas Fluxing of Al (Bubble Probe)	1.83	27.53	2008/b
	Processing of Aluminum Wastes	1.65	8.77	2008/b
Forming	Superior Aluminum Extrusions	0.23	2.22	2006/b
	Modeling Optimization DC Casting/Ingot Cracking	2.78	4.79	2005/a
	Spray Rolling	1.36	8.15	2006/c
	Continuous Cast Al Sheet	0.28	3.41	2007/b
	Plastic Deformation Processing	0.05	0.39	2006/b

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
	Coolant Characteristics	0.02	0.19	2006/b
	Rolling Process Design Tool	0.91	8.24	2006/b
	Formability of Cast Alloys	0.28	3.41	2007/b
	Integrated Method for Thermomechanical Processing	0.09	1.02	2007/b
	Reduction of Annealing Times	0.18	2.04	2007/b
	Surface Behavior of Al Alloys	0.05	0.46	2006/b
	Two-phase Model for Hot Deformation of Highly Alloyed Al	0.02	0.26	2007/b
	Total	21.98	198.83	N/A

Total primary (counting electricity generation and transmission losses) energy savings in 2010 are projected to be about 22 trillion Btu, significantly lower than the GPRA submission for FY 2003 (76 trillion Btu). Year-2020 primary energy savings for the FY 2004 portfolio are projected at about 199 trillion Btu, nearly identical to the 2020 figures in the 2003 submission (194 trillion Btu). This represents approximately one-fourth of the industry's total energy consumption (assuming the majority of U.S. smelters are operating).

Six new university-based projects have been analyzed for the FY 2004 analysis: Gas Fluxing of Aluminum (Bubble Probe), Formability of Cast Alloys, Integrated Method for Thermomechanical Processing, Reduction of Annealing Times, Surface Behavior of Aluminum Alloys, Two-Phase Model for Hot Deformation of Highly Alloyed Aluminum. Four projects (Non-Consumable Anode for Electrowinning, Vertical Flotation Melter and Scrap Dryer, Recycling Aluminum Saltcake, and Textures in Strip-Cast Aluminum Alloys) that were part of the GPRA 2003 submission have been completed (or did not receive funding this year) and have not been included in the 2004 submission.

The energy savings totals shown in the aluminum team benefits spreadsheet reflect only the projects actually analyzed, and have not been adjusted or normalized to reflect 100% of the budget. The savings are fairly equivalent to those in GPRA 2003; the four projects dropped from last year's analysis had somewhat lower energy savings than the six new university-based projects added this year. Additionally, the GPRA methodology has changed since last year, resulting in lower energy savings for all of the projects in 2010. Using the new method, the GPRA result is the energy savings provided by the technology if OIT was not involved subtracted from the energy savings created with OIT's involvement.

There are overlapping markets between two of the projects listed above – Carbothermic Reduction and Inert Metal Anode. Each of these technologies has been assigned approximately one-third of the total potential market for primary aluminum production.

2. Chemical Industry Vision

Table 4. Chemicals Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	7.8	67	382	787	657	410
2. Energy Cost Savings (B$)	0.027	0.23	1.35	2.89	2.72	2.11
3. Carbon Reduction (MMTCE)	0.14	1.14	6.30	12.61	10.72	7.44

Projected benefits for the Chemical Industry Vision were based on analysis of 22 active R&D projects that focus on improvements in energy efficiency and environmental performance of chemical manufacturing processes. The table below identifies these projects, grouping them into separate targets including materials technology, chemical synthesis, computational technology, process science and engineering, and biotechnology. It is estimated that the current funding for these projects represents 59% of the $14.5 million FY 2003 Chemical Industry Vision Portfolio budgdet. The Chemical Industry Vision has just closed a solicitation and several new R&D projects are expected to begin after the GPRA study is completed.

Table 5. Summary of Project Runs – Chemical Industry Vision

Impact Target	Project/Spreadsheet Run File Name	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Materials Technology	Alloy Selection System/ASSET (asset.04)	11.12	107.36	2005/b
	Mixed Solvent Corrosion (alloy.corrosion.model.04)			
	Corrosion Monitoring System (corrosion.monitoring.04)	7.16	60.04	2005/b
	Alloys for Ethylene Production (intermetalics.ethylene.crackers.04)	17.01	164.30	2005/b
	Metal Dusting Phenomenon (metal.dusting.04)	0.02	0.10	2005/b
	SUBTOTAL	**35.31**	**331.8**	
Chemical Synthesis	High Throughput Catalyst Screening (highthrucatalyst.04.new)	2.82	58.63	2007/b
	Selective Oxidation of Aromatic Compounds (directoxida.04)	0.32	13.3	2009/c
	Advanced Autothermal Reformer (autothermal.04)	1.23	19.68	2005/b
	Short Contact Time Reactor (shortcontactreactor.04.new)			
	SUBTOTAL	**4.37**	**91.61**	

Computational Technology	Solution Crystallization Modeling Tools (crystallizer.optimization)	1.22	7.30	2005/b
	Multi-phase Computational Fluid Dynamics (CFD) (cfdrollup1)	1.47	12.13	2004/b
	Molecular Simulation for the Chemical Industry	0.50	14.32	2008/b
	Reaction Engineering Workbench	3.05	24.88	2005/b
	Distillation Column Modeling Tools (distillation.column.model)	6.04	84.73	2007/b
	SUBTOTAL	**12.28**	**143.36**	
Process Science and Engineering				
Separations	Membranes for p-Xylene Separation (advmat.04)	1.61	52.91	2007/b
	Mesoporous Membranes for Olefin Separations (mesopormembrane.04.new)	1.24	34.50	2007/b
	Purification Process for PTA (pta.purification)	0.28	4.38	2006/b
	Membranes for Corrosive Reactions (membranes.oxidative.reactions a)(membranes.oxidative.reactions b)	0.56	13.16	2007/b
	SUBTOTAL	**3.69**	**104.95**	
Process Engineering	Enhanced Heat Exchangers for Process Heaters (dimpletube.process.heaters)	1.29	11.08	2005/b
	Ethylene Process Design Optimization (ethylene.process.04.new)	2.6	32.84	2006/b
	SUBTOTAL	**3.89**	**43.92**	
Chemical Measurement	Accelerated Characterization of Polymer Properties (microanalysis.polymer.properties)	0.93	10.23	2008/a
Bioprocesses and Biotechnology	Development of Non-Aqueous Enzymes	5.97	60.78	2006/b
	SUBTOTAL	**6.9**	**71.0**	
	Total	66.84	786.77	

Rev. 06/28/02

Energy consumption in the chemicals industry is very complex, involving a great number of processes manufacturing thousands of products. Hydrocarbon fuels used as chemical feedstocks, according to the 1998 MECS, accounted for about 2.7 quads of energy use, about 46% of the industry's 6 quads of primary energy use. Separations and process heating are responsible for much of the remaining energy use. It is reported that distillation, one of the most widely used separation processes in the chemical

industry, accounts for as much as 40% of the industry's total energy use for heat and power. The Chemical Industry Vision focuses much of its efforts on these energy intensive processes, and on improving the efficiency and yield of chemical processes.

Total primary energy savings in 2010 for the Chemical Industry Vision are projected to be about 67 trillion Btu, approximately one-third the GPRA submission for FY 2003 (233 trillion Btu). Year 2020 energy savings for the FY 2004 portfolio are projected at about 786 trillion Btu, which is at the same level as the GRPA submission for FY 2003. For comparison, year 2010 projected energy savings are about 1% of 2000 energy use in the chemicals industry (6,064 trillion Btu).

Changes from the GPRA 2003 submission are due to the deletion of 13 projects and changes in the market penetration model. The large decrease in 2010 is due primarily to changes in the model.

3. Forest Products Industry Vision

Table 6. Forest Products Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	0.12	14	97	267	344	371
2. Energy Cost Savings (B$)	0.0004	0.04	0.24	0.70	0.94	1.06
3. Carbon Reduction (MMTCE)	0	0.15	1.01	2.74	3.53	3.80

Projected benefits for the Forest Products Industry Vision were estimated using an analytical process very different from that used in years past. In past years, the GPRA summary submission was based on a roll-up of the results from spreadsheet analyses of the individual projects funded in the current fiscal year. For example, the FY03 GPRA submission was a rollup of 56 of 60 active R&D projects funded by the program in FY02. For the FY04 GPRA process, the analysis was focused on 13 different *energy focus areas* into which 37 active R&D projects were grouped. That is, spreadsheet analyses were done to estimate benefits of the specific focus areas (e.g., Recovery Boiler Efficiency or Paper Drying) rather than of the individual projects that address each area. In this way, overlap between projects that address similar markets is avoided and a more accurate assessment of the ultimate potential is achieved. Table Y shows the summary of GPRA 2004 benefits achievable in each of these focus areas, and a list of the projects that fall into each area. It is estimated that the 37 projects represent over 74% (more than $7.4 million) of the $10.03 million FY 2003 budget for the Forest Products Industry Vision (remainder is for new awards and non-R&D activities).

The FY04 energy savings estimates are significantly less than those projected in FY03 because black liquor gasification is not included in this year's GPRA analysis for Forest Products (the gasification projects have been moved to EERE's Office of the Biomass Program). Without gasification, the estimates are very close for the year 2020: the FY03 estimated energy savings was 257 trillion Btu and in FY04 the estimate is 266. For the year 2010, the numbers are significantly lower in FY04 (14 trillion Btu compared to almost 80 trillion Btu in FY03) due to later estimates for market introduction.

The current portfolio includes projects that were selected by competitive solicitations issued cooperatively by DOE and the American Forest & Paper Association (AF&PA). Target areas for the solicitations were developed by expert task groups and were based on the forest products industry's vision and technology roadmaps.

Table 7. Summary of Project Runs – Forest Products Industry Vision

Impact Target and Projects	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Improved Pulping Yield & Decreased Pulping Energy • Molecular Physiology of Nitrogen Allocation • Dominant Negative Mutations of Floral Genes • Genetic Augmentation of Syringyl Lignin in Low_lignin Aspen Trees • Quantifying and Predicting Wood Quality of Loblolly and Slash Pine Under Intensive Forest Management • Exploiting Genetic Variation of Fiber Components and Morphology in Juvenile Pine • Environmental Influences on Wood Chemistry and Density of Populus and Loblolly Pine • Accelerated Stem Growth Rates and Improved Fiber Properties of Loblolly Pine • Increasing Yield of Kraft Cooks Using Microwaves • Novel Pulping Technology: Directed Green Liquor Utilization (D_Glu) Pulping	1.8	35.6	2007/b
Recovery Boiler Efficiency • Materials for Kraft Recovery Boiler • Intermediate_sized, Entrained Particles • CFD Modeling, Shape Optimization and Feasibility Testing of Advanced Black Liquor Nozzle Designs • Improved Recovery Boiler Performance Through Control of Combustion, Sulfur and Alkali Chemistry • Development of Corrosion Resistant Chromium Rich Alloys for Gasifier and Kraft Recovery Boiler Applications	3.4	60.8	2007/b
Paper Drying • Multiport Cylinder Dryers • Uniform Web Drying Using Microwaves • Laboratory Development of a High Capacity Gas_Fired Paper Dryer • Development of a Continuous Process for Displacement Dewatering	2.2	46.8	2007/b
Decreased Paper Basis Weight for Paperboard • On_Line Fluidics Controlled Headbox • The Lateral Corrugator • Acoustic Foils for Enhanced Dewatering and Formation • Contactless Monitoring of Paper • Non_Contact Laser Acoustic Sensor	2.3	45.9	2007/b
Bleaching • High Selectivity Oxygen Delignification • Higher Selectivity Oxygen Delignification	1.0	18.4	2007/b
Causticizing • Use of Borate Autocausticizing to Supplement Lime Kiln and Causticizing Capacities	0.6	12.7	2007/b
VOC/HAP Emission Control • Plasma Technologies for VOCs • Improving Dryer and Press Efficiencies Through Combustion of Hydrocarbon Emissions	1.0	19.9	2007/b

Impact Target and Projects	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Improved Paper Machine Efficiency • Screenable Pressure Sensitive Adhesives • Decontamination of Process Streams Through Electrohydraulic Discharge	0.06	1.07	2007/b
Recycling OCC • Preventing Stength Loss of Kraft Fiber	0.4	7.8	2007/b
Deinking • Surfactant Spray to Improve Flotation Deinking	0.06	0.09	2007/b
Wood Boiler Efficiency • Methane de_NOX	1.0	7.1	2004/b
Lumber Drying • Microwave Treatment for Rapid Wood Drying • Wireless Microwave Wood Moisture Measurement System for Wood Drying Kilns	0.2	4.7	2007/b
Wood Panel Pressing • Fast Curing of Composite Wood Products • Rapid, Low Temperature Electron X_Ray and Gamma Beam Curable Resins	0.3	4.9	2007/b
TOTAL	**14.32**	**265.76**	

4. Glass Industry Vision

Table 8. Glass Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	1.1	8	40	68	47	18
2. Energy Cost Savings (B$)	0.004	0.03	0.16	0.29	0.21	0.08
3. Carbon Reduction (MMTCE)	0.02	0.12	0.54	0.87	0.60	0.25

Projected benefits for the Glass Industry Vision were based on analysis of 15 active R&D projects addressed to improvements in energy efficiency and environmental performance of glass manufacturing processes. The table below identifies these projects, grouping them into separate targets including modeling/simulation, sensors/control, combustion, furnace technology, and glass composition/properties/finishing. It is estimated that these projects represent approximately 90% of the latest fiscal year's R&D budget. The FY 2003 budget for Glass Industry Vision is $4.6 million.

Energy consumption in the glass melting industry is dominated by the use of natural gas in melting furnaces. Four major industry segments use somewhat differing process equipment to produce container glass, flat glass, fiber glass, and pressed/blown glass. In the United States, approximately 380 furnaces currently produce 18.16 million tons of product annually; these furnaces range in size from pressed/blown specialty glass melters under 75 TPD capacity to flat/float glass melters of more than 550 TPD capacity.

Table 9. Summary of GPRA 2004 Benefits – Glass Industry Vision

Impact Target	Project/Spreadsheet Run File Name	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Modeling/ Simulation	Modeling of Glass Processes (Modeling.Glass.Processes.04)	0.61	4.42	2003/c
	Validation of Coupled Combustion Space/Glass Bath Furance Simulation (Coupled.Bath.Simulation.03)	0.53	7.11	2006/b
	Process Optimization for On-line Coating of Float Glass (glasscoating.04.new)	0.0	0.12	2005/b
	Diagnostics and Modeling of High Temperature Corrosion of Refractories (Diagnostics.Corrosion.Refractories.Furnaces.03)	1.24	10.30	2005/b
	Subtotal	**2.38**	**21.95**	na
Sensors/ Control	Molybdenum Disilicide Composites for Glass Sensors (MolyDisilicideComposites.Sensor.04)	0.24	0.71	2004/b
	Monitoring/Control of Alkali Volatization and Batch Carryover (controlalkalibatch.04.new)	0.35	3.46	2005/b
	Measurement and Control of Glass Feedstocks (controllibs.market1.04,controllibs.market2.04)	0.29	2.85	2005/b
	Advanced Process Control for Glass (Auto.Sideglass.Control.04)	0.75	4.45	2004/b
	Auto Glass Process Control (Auto.Glass.Process.Control.04)			
	Subtotal	**1.63**	**11.47**	na
Furnace Technology	High-Luminosity Low Nox Burner (High-Luminosity.LowNOx.Burner.04)	0.29	0.90	2003/b
	Integrated Batch Preheater (batchpreheatcontainer.04.new, batchpreheatflat.04.new,batchpreheatspecial.04.new)	0.85	8.41	2003/b
	Glass Furnace Combustion and Melting User Facility (User.Facility.04)	1.27	11.96	2005/b
	Subtotal	**2.41**	**21.27**	na
Glass Composi-tion/Properti es/Finishing	Enhanced Cutting and Finishing of Handglass With a Laser (Laser.Cutting.ofGlass.04)	0.37	1.10	2003/b
	Integrated Ion Exchange System for High Strength Glass Products (Ion.Exchange.Strength.04)	1.02	9.70	2005/b
	Recovery/Recycling of In-house Glass Manufacturing Waste (glassrecycle.04.new)	0.30	2.68	2005/b
	Subtotal	**1.69**	**13.48**	na
	Grand Total	**8.12**	**68.17**	na

Total primary energy savings in 2010 are projected to be about 8 trillion Btu, approximately 74% lower than the GPRA submission for FY 2003 (31 trillion Btu). Year 2020 energy savings are projected to be 68 trillion Btu, approximately 14% lower than the GPRA submission for FY2003 (79 trillion Btu). For comparison, the year-2010 projected energy savings are 3% of MECS 1998 primary energy consumption in the glass industry (293 trillion Btu). Our year-2020 projected energy savings are 23% of MECS 1998 primary energy consumption in the glass industry.

Changes from the GPRA 2003 submission, which occur mostly in the near-term, are due to a change in the model. In addition, three projects have been removed from this year's submission.

5. Metal Casting Industry Vision

Table 10. Metal Casting Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	0.8	23	63	101	116	116
2. Energy Cost Savings B$/yr	0.03	0.11	0.31	0.53	0.61	0.62
3. Carbon Reduction (MMTCE)	0.02	0.47	1.19	1.83	2.10	2.08

Projected benefits for the Metal Casting Industry Vision were based on analysis of 29 active R&D projects to improve energy efficiency in metal casting processes. The table below identifies these projects, grouping them into separate targets areas. It is estimated that these projects represent approximately 83% of the $5.3 million FY 2003 budget the Metal Casting Industry Vision. Where appropriate, market penetration estimates took into account multiple projects addressing a particular target area. Also where appropriate, multi-phase projects were combined into one spreadsheet.

Energy consumption in the metal casting industry is dominated by the use of electricity and natural gas. Coal/coke also is used. An estimated 55% of energy used in metal casting processes is used in melting. Metal casters use a variety of furnace types including electric melting furnaces, electric arc furnaces, induction furnaces, fuel-fired furnaces and cupolas. Other energy intensive operations include molding and heat treating. The U.S. metal casting industry is diverse. Castings are produced from gray and ductile iron, steel, aluminum and aluminum-based alloys, copper, magnesium, zinc and other metals. The industry is composed of nearly 2,950 foundries and die casters manufacturing metal products using a variety of casting processes. The most common casting processes are sand casting, permanent mold casting, die casting and investment mold casting. The lost foam casting process, which has traditionally represented a small share of casting production, is seeing a rapid increases due to the deployment of research findings.

In prior years, 1994 baseline energy consumption was estimated at 200 Trillion Btu. In 1998, energy use in the foundry industry (NAICS code 3315) was 235 trillion Btu (Source: DOE/EIA 1998 MECS). If captive foundries are included, the estimated energy consumption for metal casting increases to 328 trillion Btu. The Metal Casting Industry of the Future is co-funding research to improve efficiency in the industry and to reduce energy consumption in metal casting operations. It is funding research in industry defined areas for manufacturing technologies, materials technologies, products and markets, and environmental technologies.

Total primary energy savings in 2010 are projected to be about 23.38 trillion Btu, approximately 32% less than the GPRA submission for FY 2003 (34.49 trillion Btu). Year 2020 energy savings for the FY 2004 portfolio are projected at about 101.01 trillion Btu, 25% greater than the GPRA submission for FY 2003 (75.34 trillion Btu). For comparison, the year-2020 projected energy savings are 50.5% of 1994 primary energy consumption in the metal casting industry (200 trillion Btu); 43% of the 1998 energy consumption; and 13% of an informal OIT baseline projection for 2010 (264 trillion Btu).

Changes from GPRA 2003 submissions are most significant in the 2010 time frame and 2020 time frame. This is due to several factors. The model used for GPRA 2004 applies a market penetration curve that is inversed when compared to 2003. In addition, reported energy savings for GPRA 2004 represent the delta between energy saved with and without OIT involvement. This measures the role of OIT in the projected energy savings.

Table 11. Summary of Project Runs – Metal Casting Industry Vision

Impact Target	Project Name	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Computer-based Modeling Tools	Development of computational fluid dynamics tool for modeling bead expansion in lost foam	0.05	0.59	2004/b
	Computer modeling of the mechanical performance of die casting dies	2.03	4.48	2005/a
Die Life Extension/Die Performance	Surface Engineered Coatings for Die Casting Dies	0.01	0.05	2004/b
	Improved Design, Operation and Durability of Shot Sleeves	0.01	0.05	2007/b
	Integration of RSP Tooling in die casting	0.48	5.42	2005/b
Materials properties and performance (molds, dies, and castings)	Development Program for Natural Aging Aluminum Alloys	0.15	0.37	2005/a
	Determination of Bulk Dimensional Variation in Castings	0.34	2.92	2005/b
	Grain refinement of Permanent mold cast copper base alloys	0.14	1.64	2006/b
	Creep resistant zinc alloy development	0.23	1.77	2005/b
	Investment shell cracking	0.08	0.81	2005/b
	Service performance of welded duplex stainless steel castings	0.01	0.07	2006/b
Thin Wall/High Strength castings	Thin wall cast iron	0.10	2.38	2007/b
	Clean, machinable thin walled gray and ductile iron casting	0.36	2.19	2004/b
Advanced casting methods	Lost Foam	6.15	10.23	2004/a
	Investigation of Heat Transfer at the Mold/Metal Interface in Permanent Mold-Casting of Light Alloys	0.10	2.61	2007/b

	Metallic Reinforcement of the squeeze casting process	0.11	1.24	2005/b
Machining; inclusions, porosity reduction	Advanced Steel Technology	2.21	4.70	2005/a
	Prevention of porosity formation and other effects of gaseous elements	0.13	1.64	2006/b
	Improvements in sand/mold/cor technology: effect on casting finish	0.40	4.99	2006/b
Energy guidelines; Emissions Reduction; Byproduct Reuse	Energy consumption in die casting operations	1.80	3.99	2005/a
	Metallic Recovery and Ferrous Melting Processes	0.05	0.17	2006/a
	Non-incineration treatment to reduce benzene emissions	5.42	10.48	2005/a
	Technical data to validate foundry byproducts in hot mix asphalt	0.01	.03	2006/a
Sensors	Sensors for die casting	0.24	2.35	2005/b
Steel Foundry Practices (e.g. gating, heat treating, process re-engineering)	Re-engineering casting production systems	0.10	0.73	2004/b
	Yield Improvement in Steel Castings	2.27	30.98	2006/b
	Heat Treatment procedure qualification for steel casting	0.17	0.35	2005/a
Die Casting Practices (e.g. gating, process control, die filling, etc)	Ultrahigh speed measurement of internal die cavity temperature for process control	0.18	2.58	2006/b
	Effect of externally solidified product on wave celerity	0.08	1.21	2006/b
	Grand Total	**23.41**	**101.02**	**na**

6. Steel Industry Vision

Table 12. Steel Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	2.8	43	145	212	143	39
2. Energy Cost Savings (B$)	0.01	0.12	0.44	0.62	0.40	0.11
3. Carbon Reduction (MMTCE)	0.05	0.93	3.57	6.52	5.26	1.6

The GPRA submission for the Steel Vision is based on analysis of 27 technologies related to enhancing the productivity, energy efficiency, and environmental performance of steel manufacturing processes (see table below). The Steel Team's FY 2003 budget is approximately $10.3 million. The projects listed

below represent approximately 42% of the budget, compared to the 80% figure for the 24 projects analyzed for the GPRA 2002 submission.

The mission of the OIT Steel Program is to support pre-competitive, higher-risk technologies and processes through cost-shared public-private partnerships. Revolutionary ironmaking and steelmaking technologies that will benefit the industry as a whole are ideal candidates for DOE support because of their enormous potential payoff. The DOE Steel Program has devised a strategy to foster both revolutionary ironmaking and steelmaking projects and incremental improvements to existing processes, thereby addressing long-term goals without neglecting short-term needs. The Program has also expanded the industry's fundamental base of knowledge to optimize key processes and resource efficiency. Since 2001, the Steel Program has been redirecting its portfolio to focus more on revolutionary steelmaking concepts rather than incremental improvements to existing processes in order to achieve maximum energy savings. This transition in the Program's strategy should produce dramatic drops in steelmaking energy intensity over the long term.

Table 13. Summary of Project Runs – Steel Industry Vision

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Processes	Advanced Process Controls for Integrated Mills	12.6	5.1	2004/a
	Hot Oxygen Injection into the Blast Furnace	3.6	1.5	2004/a
	Quantifying the Thermal Behavior of Slags	1.0	7.7	2005/b
	Automated Steel Cleanliness Tool**	1.6	1.6	2005/a
	Magnetic Gate for Molten Metal Flow Control	1.1	0.5	2004/a
	QMST	0.2	1.2	2005/b
	Investigation of Deadman/ Hearth Region of Blast Furnace	0.8	19.8	2008/b
Combustion/ Environment	NO x Emission Reduction by Oscillating Combustion	2.1	0.8	2004/a
	Dilute Oxygen Combustion	2.1	14.5	2004/b
	Nitrogen Control in EAF Steelmaking by DRI Fines Inject	2.0	17.9	2005/b
	Quality Improvement of Waste Oxide Briquettes	0.3	10.1	2009/a
	Optical Sensor for EAF Post-Combustion Control	0.5	2.5	2004/b
	Optimization of Post-Combustion in Steelmaking	1.5	7.6	2004/b
	Sustainable Steelmaking Using Biomass and Waste Oxides	1.4	25.0	2007/b
Materials	Intermetallic Alloys For Steel	0.8	10.8	2006/b

	Improved Refractory Service Life and Recycling Refractory Materials	0.8	4.2	2004/b
	Development of Submerged Entry Nozzles that Resist Clogging	2.1	14.5	2004/b
Quality	Inclusion Optimization for Next Generation Steel Products	0.3	5.1	2007/b
	Laser-Assisted Arc Welding of Advanced HSS	0.9	2.0	2006/a
	Resistance Spot Welding for HSS	0.9	2.1	2006/a
	Electromagnetic Filtration of Molten Steel	0.6	14.0	2008/b
	Controlled Thermo-Mechanical Processing of Tubes and Pipes	0.6	4.0	2007/a
	Development of Steel Foam Materials and Structures	0.6	6.5	2006/b
	Clean Steels – Advancing the State of the Art	3.2	27.3	2005/b
	Formability of HSS steels	0.4	1.8	2004/b
	Fatigue/Crash Performance HSS	0.2	1.9	2006/b
	Hydrogen and Nitrogen Control in the Ladle and Casting	1.2	2.5	2006/a
	Total	**43.4**	**212.2**	

Total primary (counting electricity generation and transmission losses) energy savings in 2010 are projected to be 43.4 trillion Btu, compared to 70.8 trillion Btu in GPRA 2003. Year-2020 primary energy savings for the FY 2004 portfolio are projected at about 212.5 trillion Btu, compared to 151 trillion Btu last year. For comparison, 1998 primary energy consumption for the steel industry was 1.68 quads. The projected savings in year 2010 are approximately 2.5% of the projected baseline energy use in the industry.

Three projects analyzed for GPRA 2003 were dropped from this analysis (Non-Cr Passivation, PCI Coal Combustion Behavior, and Laser-Assisted Arc Welding) because they were completed. Six new steel projects were added to the GPRA 2004 analysis. None-the-less, the primary energy savings results for 2010 are lower than in last year's analysis because most of new projects will not be commercialized until 2007. The energy savings for 2020 are much higher than last year because the new projects will result in significantly higher savings. Additionally, the GPRA methodology has changed since last year, resulting in relatively lower energy savings for all of the projects. Using the new method, the GPRA result is the energy savings provided by the technology if OIT was not involved subtracted from the energy savings created with OIT's involvement.

The project entitled "NOx Emission Reduction by Oscillating Combustion" is being funded entirely by the steel team, even though it has potential benefits in a number of other industries. The only benefits counted in the steel team benefits roll-up are those directly attributable to steel industry applications.

There are no overlapping markets in any of the areas listed above. The Oscillating Combustion technology can be used in conjunction with Dilute Oxygen Combustion and does not represent an overlap.

The energy savings totals shown in the steel team benefits spreadsheet reflect only the projects actually analyzed, and have not been adjusted or normalized to reflect 100% of the budget.

7. Mining Industry Vision

Table 14. Mining Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	5.4	29	100	205	339	441
2. Energy Cost Savings (B$)	0.024	0.15	0.55	1.19	2.02	2.70
3. Carbon Reduction (MMTCE)	0.11	0.60	2.00	4.05	6.99	8.72

The Mining Industry of the Future program is currently funding 28 active R&D projects. Projected benefits for the Mining Industry Vision were based on analysis of 22 of these projects that address the metal, coal, and industrial mineral mining industry through improved safety, enhanced economic competitiveness, reduced energy consumption, and reduced environmental impacts. The table below lists the projects evaluated, merging them where appropriate. These projects represent approximately 76% of the $5.1 million FY 2003 budget for the Mining Industry Vision.

Where appropriate, market penetration rates were adjusted in projects within the same impact target area to correct for any potential overlap in energy savings. The two alternative fuel projects were combined into one energy benefits spreadsheet because they are part of a multiphase research effort.

Table 15. Summary of Project Runs – Mining Industry Vision

Impact Target	Spreadsheet Run File Name	Energy Savings 2010 (Trillion Btu)	Energy Savings 2020 (Trillion Btu)	Year of Intro/Market Selector
Materials	Cellular-03	0.34	2.74	2006/c
Sensors	Grader-03	0.15	0.90	2004/b
	Imaging-03	0.21	1.37	2004/c
	Geophone-03	3.09	22.90	2004/c
	Libs-03	2.84	19.62	2004/c
Alternative Fuels	Fuelcell-03 PhaseII-03	0.36	2.82	2005/c
Modeling	Comminution-03	1.72	11.74	2005/c
	Sag-03	1.44	9.36	2004/c
Communications	Communications-03	.012	0.84	2005/c
Processing	DMC-03	0.44	2.17	2004/b
	Analyzers-03	1.12	9.84	2005/b
	Byprodrecov-03	7.17	46.84	2004/b
	Flocculation-03	0.37	2.43	2004/c
	Anode	1.65	11.76	2006/c
	Screens	4.31	31.91	2007/c
Excavation	Cutting-03	0.05	0.33	2005/c
	Bolter-03	0.69	6.06	2005/b

	Robotics-03	0.26	1.71	2004/c
	blasting-03	3.01	18.65	2004/b
	Projectile-03	0.07	0.48	2006/c
	oilpro-03	0.02	0.16	2004/b
Total		**29.3**	**204.6**	

Total primary energy savings in 2010 are projected to be about 29.3 trillion Btu. Year 2020 energy savings for the FY 2004 portfolio are projected at about 204.6 trillion Btu. For comparison, the year-2010 projected energy savings are 2.6% of 2001 primary energy consumption in the mining industry (1,125 trillion Btu) and 2.4% of an informal OIT baseline projection for 2010 (1,230 trillion Btu). Our year-2020 projected energy savings are 18.2% of 2001 primary energy consumption in the mining industry and 16.6% of the OIT-calculated baseline for 2010 (DOE's Energy Information Administration does not collect mining industry data and no baseline projection for 2020 is available).

GPRA 2004-projected energy savings in 2010 are 61% lower than in 2003 GPRA (76.1 trillion Btu); GPRA 2004 shows year-2020 savings 22% higher than in GPRA 2003. Assumptions made for the 2003 GRRA were updated with more current data. Also, market penetration rates were updated with more current data. The percent of the 2004 budget captured in GPRA remained the same as GPRA 2003 at 80%. The table above indicates the year of market introduction assumed and the letter selector assigned to characterize the technology's market penetration in the spreadsheet model.

8. Petroleum Refining Industry Vision

Table 16. Petroleum Refining Industry Vision - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	4.2	34	146	175	125	119
2. Energy Cost Savings (B$)	0.01	0.12	0.56	0.72	0.55	0.56
3. Carbon Reduction (MMTCE)	0.06	0.52	2.24	2.83	2.26	2.29

Projected benefits for the Petroleum Refining Industry Vision were based on analysis of all active R&D projects (six projects) addressed to improvements in refinery operations. The table below identifies these projects, grouping them into separate targets including hydrotreating, pressure vessel integrity, facility emission control, improving hydrocarbon production process control, improving combustion efficiency, and substituting membrane separation for distillation. These projects represent the $2.80 million FY 2003 budget.

Table 17. Summary of Project Runs – Petroleum Refining Industry Vision

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Hydrotreating Energy Use	Broadening Enzyme Selectivity and Improving Activity for Biological Desulfurization and Upgrading of Petroleum Feedstocks	1.3	17.0	2005/c

Pressure Vessel Integrity	Assuring Mechanical Integrity of Refinery Equipment Through Global On_Stream Inspection	1.5	14.5	2005/b
Facility Emission Control	Hydrocarbon Leak Detector	1.7	17.0	2005/b
Process Control of hydrocarbons	Micro_GC Controller for Petrochemical Application	1.7	12.0	2004/b
Combustion Efficiency	Rotary Burner Demonstration	26.6	81.0	2004/b
Distillation Energy Use	Energy Saving Separation Technologies for the Petroleum Industry	1.6	33.3	2005/b
	Total	34.4	174.8	na

Total primary energy savings in 2010 are projected to be about 34.4 trillion Btu, approximately -5% of the GPRA petroleum Refining submission for FY 2002 (36.1 trillion Btu). Year 2020 energy savings for the FY 2002 portfolio are projected at about 175 trillion Btu, about a 26% increase of the GPRA submission for FY 2002 (139 trillion Btu). For comparison, the "1994 Manufacturing Energy Consumption Survey" (94MECS) lists the petroleum refining industry as consuming approximately 3.153 quads for combustion and power plus 3.110 quads in the form of fuels used as feedstocks. The largest energy-consuming operations in petroleum refining are atmospheric and vacuum distillation, hydrotreating, reforming, fluid catalytic cracking and catalytic hydrocracking.

Changes in primary energy savings from the GPRA 2003 submission are due to:

- changes in the methodology for calculating the impact - The new analyses measure only the energy saved as a result of technology acceleration
- changes in the technology class and year of entry - These changes were the result of discussions with industry experts during the Petroleum Portfolio review.
- changes in the unit energy impact - These changes were a result of the industry experts input and recognize the fact that four projects have impact that extends beyond the refining industry

9. Industrial Materials Crosscut

Table 18. Industrial Materials for the Future Program - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	2.8	19	90	280	407	393
2. Energy Cost Savings (B$)	0.003	0.048	0.28	0.94	1.29	1.18
3. Carbon Reduction (MMTCE)	0.01	0.21	1.18	3.71	4.84	4.14

The GPRA submission for the Industrial Materials of the Future (IMF) Program is based on a spreadsheet benefits analysis of technical innovations under development by 35 projects, which are listed in the table below. The portfolio consists of 29 new projects from a competitive solicitation in 2001 and 6 projects carried over from previous years. Research in the 29 new projects is being lead by three types of research organizations – universities (11 projects), federal laboratories (10 projects), and industry (8 projects). The six projects carried over from the FY2003 GPRA analysis include Intermetallics for Ethylene Cracking;

Intermetallic Alloy Development for the Steel Industry; Intermetallic Alloy Development for Heat Treat Carburization; Boiler Tubes; Infrared Aluminum Billets Forging; and Infrared Die Heating.

Most of the technologies under development have applications in multiple industries but the benefit estimates were typically based upon a single application of a technology. In a few instances multiple applications were considered. For example, three refractories projects have applications in both the glass and aluminum industries and thus have two listings in the table below.

The 35 projects represent about $7.232 million (53%) of IMF's $13.7 million FY2003 R&D budget. The energy savings totals shown in the IMF benefits spreadsheet reflect only the projects actually analyzed, and have not been adjusted or normalized to reflect 100% of the budget.

Table 19. Summary of Project Runs – Industrial Materials for the Future

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
H-Series Steel Alloy	Stronger and More Reliable Cast Austenitic Stainless Steel	0.8	31.9	2009/b
	Semi-Stochastic Algorithm for Optimizing Alloy Composition High-Temperature Austenitic Stainless Steels	0.1	2.8	2009/c
	Combinatorial Methods for Alloy Design and Optimization	0.1	1.2	2010/c
	Inverse Process Analysis for the Acquisition of Thermophysical Property Data	0.2	1.7	2005/c
	Ultrasonic Processing of Materials	0.0	0.1	2005/c
Cr-W(V) Steel Alloys	New Class of Fe-3Cr-W(V) Ferritic Steels	0.6	15.6	2008/b
	Fracture Toughness and Strength in a New Class of Bainitic Chromium-Tungsten Steels	0.1	3.1	2008/b
Coatings	High Density Infrared (HDI) Transient Liquid Coatings for Improved Wear and Corrosion Resistance	0.3	8.2	2008/b
	Advanced Composite Coatings	0.0	2.7	2012/c
	High Energy Density Coating of High Temperature Advanced Materials	0.0	0.2	2010/c
Carbon-Based Coatings	Ultrananocrystalline Diamond (UNCD) Coatings for SiC Multipurpose Mechanical Pumps	0.9	20.9	2008/b
Refractories	Novel Carbon Films for Next Generation Rotating Equipment	0.1	4.7	2009/b
	Ceramic and Refractory Components for Aluminum Melting and Casting (Aluminum Refractories)	0.1	3.4	2009/b
	Ceramic and Refractory Components for Aluminum Melting and Casting (Glass Refractories)	0.3	10.2	2008/b

	Modeling of Magnesia-Alumina Spinel Glass Tank Refractories	0.0	0.9	2008/b
	Advanced Nanoporous Composites for Industrial Heat Applications	0.0	0.4	2010/b
	High Density Infrared Surface Treatments of Refractories (Aluminum)	0.0	0.5	2009/b
	High Density Infrared Surface Treatments of Refractories (Glass)	0.0	0.9	2008/b
	Thermochemical Models and Databases for High Temperature Materials (Aluminum Refractories)	0.0	0.5	2009/b
	Thermochemical Models and Databases for High Temperature Materials (Glass Refractories)	0.0	0.9	2008/b
Corrosion-Resistant Materials	Stress-Assisted Corrosion in Boiler Tubes	0.5	13.7	2008/b
	Physical and Numerical Analysis of Extrusion Process for Production of Bi-Metallic Tubes	0.1	3.3	2009/b
	Co-Extrusion Technology for Tubes/Pipes	0.0	1.7	2009/b
Wear Resistant Materials	Virtual-Welded Joint Design Integrating Advanced Materials and Processing Technologies	0.5	13.8	2009/b
	Advanced Wear and Corrosion Resistant Systems through Laser Surface Alloying and Materials Simulation	0.0	0.4	2007/b
	New Class of Ultra-Hard Borides	0.4	5.4	2007/b
	Super Hard Materials	0.0	0.7	2010/b
Stand Alone – Process Materials	Novel Modified Zeolites for Energy Efficient Hydrocarbon Separations	1.3	38.1	2009/b
Stand Alone – Process Materials	Oxide-Dispersion-Strengthened Tubes for Ethylene	0.0	6.7	2014/b
Stand Alone – Chlor-Alkali Cell	Advanced Chlor-Alkali Technology	0.8	6.4	2010/c
Stand Alone – Tools & Dies	Advanced Tooling Alloys for Molds and Dies	0.1	5.6	2010/c
Stand Alone – Novel Processing	Ultrahigh Magnetic Field Processing of Materials	0.6	5.1	2007/c
Stand Alone - Ethylene cracking	Intermetallics for Ethylene Cracking	4.8	32.9	2004/c
Stand Alone - Steel casting; heat	Intermetallic Alloy Development for Steel	0.4	2.9	2005/c
Stand Alone - Steel - heat treating	Intermetallic Alloy Development for Heat Treating Carburization	3.7	21.8	2004/b
Stand Alone - Kraft	Boiler Tubes	1.7	9.6	2004/c
Stand Alone - Aluminum and titanium forging	Infrared Aluminum Billets Forging	0.1	0.5	2004/b

Stand Alone - Aluminum and steel die heating	Infrared Die Heating	0.1	0.9	2004/b
	Total	18.9	280.1	Na

Total primary energy savings in 2010 are projected to be 19 trillion Btu, about one fourth the GPRA submission for FY 2003 (74 trillion Btu). Year-2020 primary energy savings for the FY 2004 portfolio are projected to be about 280 trillion Btu, about one third more than the 207 trillion Btu result of the GPRA 2003 analysis. The year-2010 benefits are lower in this year's analysis because most of the projects are new and therefore have later commercial introduction years than last year's projects. Benefits are also lower in 2010 because changes made to the Impacts Model resulted in lower market penetration in the early years, especially for projects with commercial introductions around 2005. The year-2020 benefits are higher in this year's analysis because of the number of projects analyzed has increased from 12 to 35.

10. Sensors and Controls Crosscut

Table 20. Sensors and Controls Program - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	0.6	8	34	47	25	5
2. Energy Cost Savings (B$)	0.002	0.03	0.14	0.21	0.13	0.027
3. Carbon Reduction (MMTCE)	0.01	0.16	0.65	0.88	0.48	0.10

Projected benefits for the Sensors & Controls (S&C) Program Vision are based on analysis of 4 active R&D projects that are aimed to improve energy efficiency and environmental performance within the nine Industries of the Future (IOF) manufacturing sectors. The table below identifies these projects, grouping them into two separate targets: (1) sensors and measurement technologies and (2) control and optimization. It is estimated that these projects represent approximately 13% of the $3.8 million FY 2003 budget.

The worldwide markets for sensing technologies and for process controls are $15 billion and $26 billion a year, respectively, with the United States being the largest provider and single national market. The major share of both the sensor and the process control markets is in the manufacturing sectors targeted by the IOF Program. The high-volume use of sensor and control technologies in IOF sectors is based on the realization that significant resource/process efficiency and waste reduction can be achieved through intelligent process control using real-time measurement information. Critical to achieving the set targets of reduction in energy use and carbon emissions by the IOF vision industries is the development and delivery of sensor and control solutions for the many unmet needs as documented in the IOF technology roadmaps. The Sensors and Controls Program aims at delivering these needed solutions with broad applicability across multiple industry sectors, with a particular focus on high-risk and high-payoff technology research, development, and demonstration activities.

Table 21. Summary of Project Runs – Sensors and Controls Program

Impact Target	Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Sensors and Measurement Technologies	Remote Material On-line Sensor	0.57	5.76	2005/b
	In-Situ, real-Time Measurement of Melt Constituents	0.94	8.29	2005/b
	Solid State Chemical Sensors for Monitoring Hydrogen	3.15	24.36	2005/b
Control and Optimization	Diagnosis and Control of Natural Gas Fired Furnaces via Flame Image Analysis	3.52	11.71	2006/a
	Total	**8.18**	**46.98**	na

Total primary energy savings in 2010 are projected to be about 8.18 trillion Btu, 10% less than the GPRA submission for FY 2003 (9.2 trillion Btu). Year 2020 energy savings for the FY 2004 portfolio are projected at about 46.98 trillion Btu, 28% greater than the GPRA submission for FY 2003 (36.8 trillion Btu).

The primary energy savings results for 2010 are lower than in last year's analysis because a change in the GPRA methodology, resulting in relatively lower energy savings for all of the projects. Using the new method, the GPRA result is the energy savings provided by the technology if OIT was not involved subtracted from the energy savings created with OIT's involvement.

Two of the ten project analyses were dropped for GPRA 2004 because they will be complete in FY02. These were the Thermal Imaging Control of Furnaces and Combustors and Cupola Furnace Control Systems. Four other projects (Tunable Diode Laser for Harsh Combustion Environments, On-line Measurement Using Laser-Based Ultrasonic System, Sensor Fusion for Intelligent Process Control, and Intelligent Extruder) were also dropped for this analysis because sufficient background data was not available. Additionally, their GPRA 2003 benefits were relatively minor as compared to the four projects in this year's analysis.

11. Combustion Crosscut

Table 22. Combustion Program - QM Rollup

Item	2005	2010	2015	2020	2025	2030
1. Primary Energy Savings (TBtu)	0	18	144	588	857	534
2. Energy Cost Savings (B$)	0.00	0.06	0.53	2.29	3.54	2.34
3. Carbon Reduction (MMTCE)	0.00	0.26	2.12	8.58	12.49	7.76

The GPRA submission for the Combustion Program is based on analysis of 3 projects (1) SuperBoiler: PM/TM Boiler Development and Demonstration, (2) Advanced, Integrated Process Heater/Burner System, and (3) Low NOx, Low Swirl Burner. The Combustion Program's FY 2003 budget is approximately $2 million, with the projects listed below representing approximately 80% of the budget.

This budget is considerably smaller than the $14.6 million FY2002 budget, due to the EERE reorganization, which transferred the Gasification project to the Biomass Program.

Table 23. Summary of Project Runs – Combustion Program

Project	Energy Savings (TBtu) 2010	Energy Savings (TBtu) 2020	Year of Intro / Market Selector
Super Boiler: PM/TM Boiler Development and Demonstration	13.7	503.3	2009/b
Advanced, Integrated Process Heater/Burner System	3.9	83.8	2007/b
Low NOx, Low Swirl Burner	0.06	0.06	2004/a
Total	**17.7**	**587.2**	

Total primary (counting electricity generation and transmission losses) energy savings in 2010 are projected to be 17.7 trillion Btu, compared to 34.2 trillion Btu in GPRA 2003. Year-2020 primary energy savings for the FY 2004 portfolio are projected at about 587.2 trillion Btu, compared to 105.8 trillion Btu last/year.

The primary energy savings results for 2010 are lower than in last year's analysis because a change in the GPRA methodology, resulting in relatively lower energy savings for all of the projects. Using the new method, the GPRA result is the energy savings provided by the technology if OIT was not involved subtracted from the energy savings created with OIT's involvement. Additionally, the GPRA energy savings for 2020 is significantly higher than last years due to a change in calculation for the Super Boiler project.

The Super Boiler is an improved gas-fired packaged boiler with high thermal efficiency and low emissions designed to replace existing boilers as they reach the end of their useful lifetimes. The technology is assumed to enter its market in 2009 with market penetration curve "b". The 2020 energy savings for this project is significantly higher than last year due to an error in previous year calculations. The SuperBoiler savings were calculated in past years using a 5% capacity factor (or 438 hours per year) whereas it should be a 50% capacity factor (or 4380 hours per year). Using the new capacity factor, therefore, increases the energy savings by a factor of 10.

The Integrated Process Heater/Burner System is for both retrofits and new advanced installation in the chemicals and petroleum industries. Market introduction in 2007 is assumed with a penetration curve "b" in the spreadsheet model. The Low NOx, Low Swirl project, added to the analysis this year, will optimize the low-swirl burner to capture the benefit of firing with partially reformed natural gas and with internal flue gas re-circulation (IFGR). Efforts will focus on designing and demonstrating a low-swirl burner with IFGR that can be scaled to large industrial boilers. Market introduction is planned for 2004, with market penetration curve "a".

B. Technical and Financial Assistance Planning Units

Two planning units – the Inventions and Innovation program and the NICE^3 program – have been removed from OIT due to reorganization since the completion of GPRA 2003. Therefore GPRA includes results for only two Technical and Financial Assistance planning units – the Industrial Analysis Center program and the Best Practices program.

The Industrial Analysis Center program and the Best Practices program were again assessed based on retrospective analysis of performance data accumulated over a period of years. Quality Metrics for these planning units assume that continuation of the programs will result in beneficial impacts proportional to documented experience at historical budget levels. These analyses assume no continuing contributions from prior program expenditures, but only assume that future expenditures will produce results proportionate to those reported for past expenditures.

1. Industrial Assessment Center (IAC) Program

Table 24. IAC Program - QM Estimation and Summary

Item	2004	2005	2006	2007	2010	2015	2020	2025	2030
1. Number of Assessment Days	750	750	750	750	750	750	750	750	750
2. Cumulative Number of Assessment Days Counted	750	1,500	2,250	3,000	5,250	5,250	5,250	5,250	5,250
3. Annual Energy Saved Per Audit (MBtu/Assessment-Year)	3686	3686	3686	3686	3686	3686	3686	3686	3686
4. Energy Saved From Assessments (TBtu)	2.76	5.53	8.29	11.06	19.35	19.35	19.35	19.35	19.35
5. IAC Assessment Replication Rate	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
6. Cumulative Number of Replications Counted	0	0	225	450	1,125	1,575	1,575	1,575	1,575
7. Annual Energy Saved From Replications (TBtu)	0	0	0.83	1.66	4.15	5.81	5.81	5.81	5.81
8. Number of Alumni Starting 25-Year Career	140	140	140	140	140	140	140	140	140
9. Number of New Energy Assessment Days Per Alumni-Year	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
10. Number of New Energy Assessments Performed	70	140	210	280	490	840	1,050	1,050	1,050
11. Cumulative Number of Alumni Energy Assessments	70	210	420	700	1,960	5,460	10,500	15,750	21,000
12. Number of Aged Energy Assessments Retired	0	0	0	0	0	350	700	1,050	1,050
13. Cumulative Number of Aged Energy Assessments Retired	0	0	0	0	0	1,050	3,850	8,400	13,650
14. Number of Alumni Energy Assessments Counted	70	210	420	700	1,960	4,410	6,650	7,350	7,350

15. Annual Energy Saved From Alumni Assessments (TBtu)	0.26	0.77	1.55	2.58	7.22	16.26	24.51	27.09	27.09
16. Additional Annual Energy Saved Per Website (TBtu/Year)	1	1	1	1	1	0	0	0	0
17. Annual Energy Saved From Website (TBtu)	1	2	3	4	7	7	7	7	7
18. Total IAC Annual Energy Saved (TBtu)	4.02	8.3	13.67	19.3	37.72	48.42	56.67	59.25	59.25
19. Energy Cost Savings (B$)	0.023	0.048	0.078	0.111	0.225	0.304	0.368	0.400	0.416
20. Carbon Reduction (MMTCE)	0.069	0.147	0.248	0.361	0.712	0.894	1.029	1.076	1.076

The Industrial Assessment Center (IAC) program benefits were supported by 20 years of actual assessment and implementation data. Energy savings were calculated and summed from four sources associated with the IAC program: (1) IAC energy assessments, (2) replication assessments within firms served by IAC, (3) assessments performed by IAC student alumni, and (4) IAC website-related energy savings.

Based on historical data on 10,525 industrial site assessments, the IAC program was assumed to result in the performance of 750 assessment days annually, each of which will save, on average, 3,686 million Btu (at source) per year during seven subsequent years over which credit was counted. After growing through year 2010, the resulting national energy savings attributed to this source levels off at 19.35 trillion Btu per year, because new assessments afterward merely replace the contributions of aged assessments no longer being counted (line 4).

Based on ORNL survey results, every ten IAC Assessments were assumed to result in three replication assessments at different sites within three years of performance. The cumulative number of replicated assessments (line 6) is 0.3 times the cumulative number of IAC assessments performed (line 2), delayed by three years. The same average energy savings per Assessment (3,686 million Btu per year) were assumed.

Estimation of the contribution of assessments (or other, equivalent professional services) performed by IAC student alumni were based on a rate of graduation across the program of 140 fully-trained students each year. It was assumed that every alumni performs 0.5 energy assessment each year for 15 years after leaving the IAC program and that each assessment subsequently saves 3,686 million Btu per year. The benefits of each energy assessment (or equivalent intervention) were assumed to persist for seven years, after which the aged energy assessment was "retired" for the purposes of this estimation. Subtracting the cumulative number of aged energy Assessments "retired" (line 13) from the cumulative number of Assessments performed (line 11) gives the number of alumni assessments counted in each year (line 14). Note that in the out-years (2020 and beyond) this source contributes more energy savings than does the continuing IAC assessment program itself.

Finally, based on a preliminary study by ORNL, the contributions of the IAC website were conservatively estimated to grow at the rate of 1 trillion Btu per year. The growth of this influence was assumed to continue for seven years beginning in 2004, so that the level of savings in 2010 was continued without further increase. This contribution was considered a placeholder pending the development of further website communication benchmark data. The FY 2003 budget request is $7.7 million.

Energy cost savings (line 19), carbon reduction (line 20), and other benefits are related to energy savings by projected fuel prices and emission coefficients given in the GPRA 2004 Data Call guidance.

2. Best Practices Program

OIT's Best Practices program is designed to change the ways industrial plant managers make decisions affecting energy use by motors, drives, pumps, compressed air, steam, combustion systems, process heat and other plant utilities. The FY 2003 budget request is $9.0 million. An overall program evaluation methodology is currently under development with the help of Oak Ridge National Laboratory. Elements and preliminary metrics are shown in Table 25. A discussion of these metrics follows. Significant changes in these approaches and metrics are likely as the program continues efforts to assess the impacts of various activities and approaches.

Dissemination of Best Practices information is achieved through a wide range of communication channels and covers a panoply of technical subjects. This analysis projects future benefits based on preliminary findings of an Oak Ridge National Laboratory study of program effects in 2001. Program activities are summarized into five main groups: Plantwide Assessments, Collaborative Technology Assessments, Training, Software Tools, and Publications. Impact estimation per implementation of best practices adopted by plants due to the influence of these five program activity areas are based upon actual program findings.

The basic methodology used in each of the five areas is very similar. First the reach is estimated. By this we mean the number of individuals touched by BestPractices information. This number is then scaled back to calculate the number of plants taking action due to this information dissemination. The scale-back factors include accounting for duplicate "touches" within the same company, the percent of companies actually taking action, and a reduction factor to discount program credit due to it being but one of multiple sources of influence. In the cases of Plantwide Assessments (PWAs) and Collaborative Technology Assessments (CTAs) no scale-back factor needed to be applied.

Plantwide Assessments (PWAs) (Lines 1 - 8)

Benefits for the Plantwide Assessments were calculated based on a three-year history. Of 23 such Plantwide Assessments conducted, 14 have completed recommendation reports. Based on these reports, potential energy savings are close to 0.4 trillion Btus per year per plant. Experience from the IAC Program indicates that roughly 50% of all recommendations are actually implemented. We expect this percent to be greater for the BestPractices program where the cost of the assessment is shared with industry, thus indicating a greater level of involvement. Nonetheless, the IAC implementation rate of 50% is being used until the BestPractices program is able to document a program-specific implementation rate. Hence the number assumed for energy savings by Plantwide Assessments is 0.2 trillion Btus per plant per year (line 7).

Table 25. Best Practices Program - QM Estimation and Summary

Item	2004	2005	2006	2007	2010	2015	2020	2025	2030
1. Plantwide Assessments (PWAs)	0	7	7	7	7	7	7	7	7
2. PWA Replication	0	0	35	35	35	35	35	35	35
3. Cumulative Number of PWA Implementations	0	7	49	91	217	427	637	847	1057

4. Plants Retired From Count Each Year	0	0	0	0	0	7	42	42	42
5. Cumulative Number of Plants Retired From Count	0	0	0	0	0	7	217	427	637
6. Net Number of Plants Still Counted	0	7	49	91	217	420	420	420	420
7. Annual Energy Saved Per Plantwide Implementation (TBtu/Plant-Year)	0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
8. Annual Energy Saved Through PWA Direct Implementation and Replication (TBtu)	0	1	10	18	43	84	84	84	84
9. Collaborative Technology Assessments (CTAs)	56	70	70	70	70	70	70	70	70
10. Cumulative CTAs	56	126	196	266	476	826	1176	1526	1876
11. CTA Plants Retired From Count Each Year	0.00	0.00	0.00	0.00	0.00	70.00	70.00	70.00	70.00
12. Cumulative Plants Retired From Counting	0.00	0.00	0.00	0.00	0.00	126.00	476.00	826.00	1176.00
13. Net CTA Plants Still Counted	56.00	126.00	196.00	266.00	476.00	700.00	700.00	700.00	700.00
14. Annual Energy Saved per CTA (TBtu/Plant-Year)	0.1186	0.1186	0.1186	0.1186	0.1186	0.1186	0.1186	0.1186	0.1186
15. Annual Energy Saved By CTAs (TBtu)	7	15	23	32	56	83	83	83	83
16. Individuals Reached Through Training	1770	2210	2210	2210	2210	2210	2210	2210	2210
17. Percent Representing Plants Taking Action	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
18. New Plants Affected Each Year	177	221	221	221	221	221	221	221	221
19. Cumulative Plants Affected	177	398	620	841	1505	2611	3717	4823	5930
20. Plants Retired From Count Each Year	0	0	0	0	0	221	221	221	221
21. Cumulative Plants Retired From Counting	0	0	0	0	0	398	1505	2611	3717
22. Net Plants Still Counted	177	398	620	841	1505	2213	2212	2212	2213
23. Average Energy Saved Per Plant Taking Action (TBtu/Plant-Year)	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051	0.051
24. Annual Energy Saved By Training (TBtus)	9	20	32	43	77	113	113	113	113

25. Software Tools Distributed	17285	21606	21606	21606	21606	21606	21606	21606	21606
26. Percent Representing Plants Taking Action	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094	0.094
27. New Plants Affected Each Year	1630	2037	2037	2037	2037	2037	2037	2037	2037
28. Cumulative Plants Affected	1630	3667	5704	7741	13851	24036	34220	44404	54589
29. Plants Retired From Count Each Year	0	0	0	0	0	2037	2037	2037	2037
30. Cumulative Plants Retired From Counting	0	0	0	0	0	3667	13851	24035	34220
31. Net Plants Still Counted	1630	3667	5704	7741	13851	20369	20369	20369	20369
32. Average Energy Saved Per Plant Taking Action (TBtu/Plant-Year)	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
33. Annual Energy Saved By Software Tools Distribution (TBtus)	50	112	174	236	422	621	621	621	621
34. Publications Packets Distributed	73039	77606	77606	77606	77606	77606	77606	77606	77606
35. Percent Representing Plants Taking Action	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034	0.034
36. New Plants Affected Each Year	2463	2617	2617	2617	2617	2617	2617	2617	2617
37. Cumulative Plants Affected	2463	5080	7697	10314	18164	31248	44332	57415	70499
38. Plants Retired From Count Each Year	0	0	0	0	0	2617	2617	2617	2617
39. Cumulative Plants Retired From Counting	0	0	0	0	0	5080	18164	31247	44331
40. Net Plants Still Counted	2463	5080	7697	10314	18164	26168	26168	26168	26168
41. Average Energy Saved Per Plant Taking Action (TBtu/Plant-Year)	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03	1.87e_03
42. Annual Energy Saved By Publication Distribution (TBtus)	5	9	14	19	34	49	49	49	49
43. Total Annual Energy Saved By Best Practices (TBtu)	70	158	253	348	633	950	950	950	950
44. Energy Cost Savings (B$)	0.399	0.905	1.449	2.009	3.779	5.956	6.158	6.405	6.661
45. Carbon Reduction (MMTCE)	1.22	2.80	4.54	6.34	11.57	17.15	17.01	16.99	16.97

The number of Plantwide Assessments of 7 per year was projected by the Best Practices program staff based on assumed level funding (line 1). The annual energy saved directly by large plants due to PWA implementations (line 8) was calculated by multiplying the annual energy saved by each plant (line 7) times the net number of plants still counted (line 6). The net number of plants still counted (line 6) equals the cumulative number of plants having entered the program (line3) less the cumulative number of plants retired from the count (line 5). Plants are retired from the count after 10 years.

The number of PWA replications was calculated by estimating that each industry leading large showcase plant entering the program would influence five other large-size plants to replicate Best Practices with a two-year time delay. Current grantees are showing strong signs of replicating at as many as 20 other plants. The assumption used for this exercise is a replication factor of 5. Program staff are in the process of documenting actual replication rates for each Plantwide Assessment recipient.

Collaborative Targeted Assessments (CTAs) (Lines 9 - 15)

A critical tool of BestPractices is the Collaborative Technology Assessment (CTA) whereby DOE experts in industrial energy management are available to provide targeted, in-plant technical assistance to identify specific systems areas for improvement. CTAs are used both as a vehicle for training and as a prelude to conducting a Showcase Demonstration. Companies interested in hosting a Showcase Demonstration can request a walk-through assessment (one to three days) to identify opportunities for increased savings and productivity in industrial systems such as motors, steam, compressed air, pumping, and process heating.

Annual energy saved by implementations from CTA's (line 15) is calculated by multiplying the net number of CTAs still counted (line 13) times the median effect of all CTA's performed to date (line 14). Energy savings from a typical CTA (0.1186 TBtus) was derived from results reported in a spreadsheet entitled, "Activity Report for FY 2001" written by Oak Ridge National Laboratory. This energy savings number is a refinement of past estimates, and will continue to be refined as the program documents actual savings.

BestPractices plans to conduct 56 CTAs per year, with a 25% replication rate in the following year. Hence line 9 shows 56 CTAs in 2004 with 70 conducted in each subsequent year - 56 directly with the aid of DOE and 14 as a residual replication effect from the prior year's CTAs.

Training (Lines 16 - 24)

Training activities continue to play a key role in the strategy of BestPractices. Program managers have emphasized the "Train the Trainer" approach to help leverage limited federal dollars. The reach represented in this section of the program projections is based upon past precedent, and is therefore felt to be conservative. Actual reach should be several times the numbers indicated due to the multiplier effect of the "Train the Trainer" approach.

Line 16 shows the number of individuals trained in BestPractice sponsored workshops. Note that as with the CTAs, the second year shows a 25% increase in reach due to replication effect carryover from the preceding year. So each ensuing year will show 1770 individuals trained directly by DOE sponsored instructors and 440 additional individuals reached by those previously trained (this number will be tracked and may turn out to be much bigger).

Based upon studies conducted on past training activities in motors, pumps, and compressed air, it is assumed that the number of individuals trained must be reduced by 90% to represent the actual number plants where implementations of program Best Practice recommendations occur. This accomplished by multiplying Individuals Reached Through Training (line 16) by Percent Representing Plants Taking Action (line 17). Those plants are cumulated and retired after 10 years (lines 19 - 21) to arrive at Net

Plants Still Counted (line 22). Line 22 is then multiplied times the Average Energy Saved per Plant Taking Action - 0.051 Tbtus (line 23) - to calculate the Annual Energy Saved By Training (line 24). Line 23 is a weighted average of training in Pumps, Process Heat, Steam, Compressed Air, and Motors at both the individual company and the regional level.

Software Tools Distribution (Lines 25 - 33)

BestPractices has a variety of resources to help address a company's energy management needs and to help facilitate energy efficiency decision-making. BestPractices offers a range of software tools and databases that can assist a plant manager in making a self-assessment of a plant's steam, compressed air, motor, and process heating systems. Software tools include: AirMaster+, Airmaster+ Qualification, MotorMaster+ 3.0, Pumping System Assessment Tool (PSAT), PSAT Qualification, Steam System Scoping Tool, 3E Plus, Decision Tools for Industry, and ASDMaster: Adjustable Speed Drive Evaluation Methodology and Application. A new software tool geared toward Process Heating evaluation is due out in FY 2003.

Software Tools are distributed on CD-ROM or can be downloaded from the Internet. Although the program has a fairly good count of the number of software tools distributed, less is known about their actual use and impact. ORNL has been commissioned to explore the impact of software tool distribution. For purposes of this exercise it has been assumed that the average energy saved per plant taking an action due to software tool use is 0.03 TBtus per plant-year (line 32), or about 25% of the value of a CTA (line 14), and about 60% of the value of direct training (line 23).

The number of plants affected by the software distribution is estimated by taking the total number of pieces of software distributed (line 25), multiplying that number by the Percent Representing Plants Taking Action (line 26) to account for multiple copies going to different people at the same plant site and to account for those plants that are not ready or able to take action. A methodology analogous to that employed to derive the Training impact is then used to determine the Net Plants Still Counted (line 31), which is multiplied times Average Energy Savings (line 32) to calculate Annual Energy Savings due to Software Distribution (line 33).

Publication Dissemination (Lines 34 - 42)

BestPractices produces a variety of publications that are distributed in hardcopy or can be downloaded from the Internet. These publications include Technical Publications (e.g., Fact Sheets, Tip Sheets, Best Practices Resources, Market Assessments, Sourcebooks, and Repair Documents); Case Studies; and both the Energy Matters and OIT Times newsletters. This form of information dissemination has the broadest reach, but the least discernable direct impact on energy savings per exposure. The main purpose of most of these publications is really one of raising general awareness, interest and desire to learn more so that a plant manager might then investigate options more fully (perhaps by signing up for a training session or downloading and using a software tool).

The total number of exposure through publication dissemination is estimated to be over 73,000 in 2004 and increases to 77,600 because of the 25% replication effect (line 34). This number is multiplied by 3.4% (line 35) to estimate the total number of plants where information from the publications is applied (line 36). “Average Energy Saved per Plant Taking Action (TBtus / Plant-Year)” is shown in (line 41). This estimate of 1.87 Billion Btus (not trillion) is derived from a prior study conducted by Xenergy on the effect of motor publications and the Energy Matters newsletter. Annual Energy saved by the application of information in publications (line 42) is the product of Net Plants Still Counted (line 40) times the Average Energy Saved per Plant Taking Action (line 41).

Conclusion

Total Annual Energy Saved By Best Practices (Tbtus) (line 43) is a sum of the subtotals in the five areas previously outlined: PWA (line 8), CTAs (line 15), Training (line 24), Software Tools (line 33), and Publications (line 42). Lines 44 and 45 showing the Energy Cost Savings in Billions of Dollars and Carbon Reduction in MMTCE are derived by multiplying energy prices and carbon content factors for various fuels found in EIA *Annual Energy Outlook for 2002.*

Appendix A – FY 2004 Quality Metrics Final Summary Tables

GPRA 2004 PROJECTED PROGRAM BENEFITS - OFFICE OF INDUSTRIAL TECHNOLOGIES

Planning Element	YEAR 2010			YEAR 2020			YEAR 2030		
	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)
Aluminum	22	0.09	0.55	199	1.01	5.25	144	0.80	3.21
Chemicals	67	0.23	1.14	787	2.89	12.61	410	2.11	7.44
Forest Products	14	0.04	0.15	267	0.67	2.74	371	1.06	3.80
Glass	8	0.03	0.12	68	0.29	0.87	18	0.08	0.25
Metal Casting	23	0.11	0.47	101	0.53	1.83	116	0.62	2.08
Steel	43	0.12	0.93	212	0.62	6.52	39	0.11	1.60
Mining	29	0.15	0.60	205	1.19	4.05	458	2.82	9.06
Petroleum Refining	34	0.12	0.52	175	0.72	2.83	119	0.56	2.29
IOF Specific S/T	*240*	*0.89*	*4.48*	*2014*	*7.92*	*36.7*	*1675*	*8.16*	*29.73*
Ind. Materials	19	0.05	0.21	280	0.94	3.71	393	1.18	4.14
Sensors & Controls	8	0.03	0.16	47	0.21	0.88	5	0.03	0.10
Combustion	18	0.06	0.26	587	2.29	8.58	534	2.34	7.76
C/C R&D Subtotal	*45*	*0.14*	*0.63*	*914*	*3.44*	*13.17*	*932*	*3.55*	*12*
IAC	38	0.23	0.71	57	0.37	1.03	59	0.42	1.08
Best Practices	633	3.78	11.57	949	6.16	17.01	949	6.66	16.97
TA Subtotal	*671*	*4.01*	*12.28*	*1006*	*6.53*	*18.04*	*1008*	*7.08*	*18.05*
IOF Crosscut S/T	*716*	*4.15*	*12.91*	*1920*	*9.97*	*31.21*	*1940*	*10.63*	*30.05*
Total	**956**	**5.04**	**17.39**	**3934**	**17.89**	**67.91**	**3615**	**18.79**	**59.78**

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GPRA 2004 PROJECTED PROGRAM BENEFITS - OIT PLUS ELEMENTS NO LONGER IN OIT

Planning Element	YEAR 2010			YEAR 2020			YEAR 2030		
	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)	Primary Energy Savings (TBtu)	Energy Cost Savings (Billion 2000 $)	Carbon Reduction (MMTCE)
Aluminum	22	0.09	0.55	199	1.01	5.25	144	0.80	3.21
Chemicals	67	0.23	1.14	787	2.89	12.61	410	2.11	7.44
Forest Products	14	0.04	0.15	267	0.67	2.74	371	1.06	3.80
B.L. Gasification*	26	0.13	0.54	621	3.50	12.08	966	5.67	18.79
Glass	8	0.03	0.12	68	0.29	0.87	18	0.08	0.25
Metal Casting	23	0.11	0.47	101	0.53	1.83	116	0.62	2.08
Steel	43	0.12	0.93	212	0.62	6.52	39	0.11	1.60
Mining	29	0.15	0.60	205	1.19	4.05	458	2.82	9.06
Bio-based Products*	76	0.13	0.45	948	2.66	10.05	1,832	8.69	28.22
Petroleum Refining	34	0.12	0.52	175	0.72	2.83	119	0.56	2.29
IOF Specific S/T	*342*	*1.15*	*5.47*	*3583*	*14.08*	*58.83*	*4473*	*22.52*	*76.74*
Ind. Materials	19	0.05	0.21	280	0.94	3.71	393	1.18	4.14
Sensors & Controls	8	0.03	0.16	47	0.21	0.88	5	0.03	0.10
Combustion	18	0.06	0.26	587	2.29	8.58	534	2.34	7.76
C/C R&D Subtotal	*45*	*0.14*	*0.63*	*914*	*3.44*	*13.17*	*932*	*3.55*	*12*
IAC	38	0.23	0.71	57	0.37	1.03	59	0.42	1.08
Inv. & Innov.*	207	1.07	3.95	2,190	13.78	42.72	1,558	11.03	30.61
NICE3*	5	0.02	0.08	45	0.22	0.76	38	0.19	0.62
Best Practices	633	3.78	11.57	949	6.16	17.01	949	6.66	16.97
TA Subtotal	*883*	*5.1*	*16.31*	*3241*	*20.53*	*61.52*	*2604*	*18.3*	*49.28*
IOF Crosscut S/T	*928*	*5.24*	*16.94*	*4155*	*23.97*	*74.69*	*3536*	*21.85*	*61.28*
Total	**1270**	**6.39**	**22.41**	**7738**	**38.05**	**133.52**	**8009**	**44.37**	**138.02**

*Shown only for comparison with earlier years. These planning elements will not be included in OIT GPRA 2004 portfolio.

GPRA 2004 QUALITY METRIC (QM) TRENDS – OIT PROGRAMS

Planning Element	2010 Energy Savings (TBtu)			2020 Energy Savings (TBtu)			2030 Energy Savings (TBtu)		
	'02 QM	'03 QM	'04 QM	'02 QM	'03 QM	'04 QM	'02 QM	'03 QM	'04 QM
Aluminum	78	76	22	238	194	199	479	365	144
Chemicals	112	233	67	592	786	787	1,221	1,652	410
Forest Products w/o B.L.	101	80	14	330	258	267	600	487	371
Glass	21	31	8	81	79	68	145	130	18
Metal Casting	18	35	23	71	75	101	130	117	116
Steel	59	71	43	178	151	212	263	219	39
Mining	28	76	29	118	167	205	204	239	458
Petroleum Ref.	120	36	34	466	122	175	767	234	119
IOF Specific S/T	*537*	*638*	*240*	*2074*	*1832*	*2014*	*3809*	*3443*	*1675*
Industrial Materials	22	74	19	86	207	280	146	362	393
Sensors & Controls	6	9	8	23	37	47	32	47	5
Combustion	21	34	18	103	106	587	190	183	534
C/C R&D Subtotal	*49*	*117*	*45*	*212*	*350*	*914*	*368*	*592*	*932*
IAC	44	40	38	61	58	57	62	59	59
Best Practices	175	169	633	338	438	949	501	707	949
TA Subtotal	*219*	*209*	*671*	*399*	*496*	*1006*	*563*	*766*	*1008*
IOF Crosscut S/T	*268*	*326*	*716*	*611*	*846*	*1920*	*931*	*1358*	*1940*
Total	805	964	956	2685	2678	3934	4740	4801	3615

Explanation of increases from GPRA 2003:

- Combustion – Analysts report that correction of an order-of-magnitude capacity factor error in GPRA 2003 worksheet for the Super Boiler project causes the increase.
- Best Practices – Increase is based upon a report by D. Jones, et. al., Oak Ridge National Laboratory, "Preliminary Estimation of Energy Management Metrics for the Best Practices Program," May 2002, with additional OIT staff assumptions.

GPRA 2004 QM TRENDS – OIT PLUS ELEMENTS NO LONGER IN OIT

Planning Element	2010 Energy Savings (TBtu)			2020 Energy Savings (TBtu)		
	2002 QM	2003 QM	2004 QM	2002 QM	2003 QM	2004 QM
Aluminum	78	76	22	238	194	199
Chemicals	112	233	67	592	786	787
Forest Products w/ B.L.*	277	187	40	1500	971	888
Forest Products w/o B.L.	101	80	14	330	258	267
Black Liquor Gasification*	176	107	26	1,170	713	621
Glass	21	31	8	81	79	68
Metal Casting	18	35	23	71	75	101
Steel	59	71	43	178	151	212
Mining	28	76	29	118	167	205
Bio-based Products*	15	189	76	100	545	948
Petroleum Ref.	120	36	34	466	122	175
IOF Specific S/T	*728*	*934*	*342*	*3344*	*3090*	*3583*
Industrial Materials	22	74	19	86	207	280
Sensors & Controls	6	9	8	23	37	47
Combustion	21	34	18	103	106	587
C/C R&D Subtotal	*49*	*117*	*45*	*212*	*350*	*914*
IAC	44	40	38	61	58	57
Inv. & Innov.*	21	112	207	108	283	2,190
NICE3*	9	45	5	44	121	45
Best Practices	175	169	633	338	438	949
TA Subtotal	*249*	*366*	*883*	*551*	*900*	*3241*
IOF Crosscut S/T	*298*	*483*	*928*	*763*	*1250*	*4155*
Total	1026	1417	1270	4107	4340	7738

*Planning elements not reported with OIT for GPRA 2004. These are included here only for comparison with prior years.

GPRA 2004 QUALITY METRIC (QM) TRENDS – % OF BUDGET REPRESENTED

Planning Element	% of Budget Represented			
	2001 QM	2002 QM	2003 QM	2004 QM
Aluminum	88	90	95	80
Chemicals	73	88	97	59
Forest Products	88	96	98	74
Glass	54	90	86	90
Metal Casting	52	81	95	83
Steel	45	60	80	42
Mining	42	70	80	76
Petroleum Ref.	63	90	86	100
Industrial Materials	70	60	75	53
Sensors & Controls	90	90	90	73
Combustion	na	na	60	80
IAC	na	na	na	na
Best Practices	na	na	na	na

Appendix B – Technology Impact Projections Model

A copy of the Excel-based Impact Projections Model spreadsheet system is available as a separate file called *GPRA 2004shell v5.3 06212002*.

Technology Impact Projections

The Technology Impact Projections model is used to estimate the potential security, economic, and environmental benefits resulting from research, development, and demonstration projects funded by the Office of Industrial Technologies (OIT). Benefit estimates are critical for evaluating projects and presenting the merits of both individual projects and the overall RD&D portfolio.

Proposers responding to a Solicitation or Request for Proposals should use the Technology Impact Projections model to estimate program benefits. Use of the model across all projects allows OIT to estimate the benefits of its projects in a consistent manner. The model allows you to enter key information about your proposed technology and its expected market, and then calculates the potential energy savings, cost savings, emission reductions and other project benefits.

Please provide your best estimate for each piece of information required to complete the spreadsheet (highlighted with light yellow shading). Be realistic about your estimates: if you are awarded a contract, you will be required to update this information annually. Note that not all inputs are necessarily applicable or available for all possible technologies. If you can only estimate the differential between the proposed new and the current state-of-the-art technology, reflect that in the spreadsheet by setting values for the current technology to "0". Also note that the Supplementary Table ("Additional Data" tab) only appears if non-zero values are entered for use of feedstocks, biomass, waste, or "other" energy forms. This table requests information on emission factors and costs for those energy forms.

Description

Provide an overview of the project/technology. This includes the project name, OITIS number (once project is funded), who prepared the estimates, program manager, planning unit, lab and industry contacts, and data sources.

Also provide a short summary of the technology upon which benefit estimates are based. Describe what constitutes a typical process unit for your technology, in terms of annual output (production capacity times duty factor). For simplicity, the analysis will assume that all units in the industry have the same capacity. A realistic, average, or typical unit capacity should be chosen, particularly for situations where the unit size may vary in different installations. By convention and to enable comparisons, units for the new technology and the current state-of-the-art should be equal in output capacity, even if, in reality, the new technology might have a different capacity for various reasons.

The new technology also might not be a physical item of hardware. Rather, it could be a process change, a computer model or control system, operational change or other non-physical technique. In such cases, a unit should be defined as the typical or average process or plant that would utilize the new technique. The annual energy inputs based on the expected energy consumption of the process or plant with the new technique would then be compared with annual energy consumption required by existing techniques.

Unit Inputs

Please provide key information on the performance of single installed units or applications of your technology. The performance of the new technology should be consistent with the performance goals in your proposal. For comparison, provide information on the performance of the best available technology for the application, not the average of all in-place technology units.

Energy Use

Please provide energy use per year for the new and conventional units, by fuel. Please also indicate the price of any feedstock, biomass, waste, and other fuels on the supplementary table (Additional Data tab). Prices for waste used as fuels may be negative, reflecting the avoided cost of conventional waste disposal.

Electricity - Includes direct electricity.
Natural Gas - Includes pipeline fuel natural gas and compressed natural gas.
Petroleum - Includes residual fuel, distillate fuel, and liquid petroleum gas.
Coal - Includes metallurgical coal, steam coal, and net coal coke imports.
Feedstock - Includes fossil fuels consumed in non-energy uses such as process feedstocks.
Biomass - Includes the use of biomass (for energy or as feedstock).
Wastes - Includes the use of fuels that are generated as wastes or process by-products. Examples of such fuels are refinery fuel gas, blast furnace gas, hog & bark fuel, and sewage sludge.
Other - Includes any fuels that may not be included in those listed above.
Total Primary Energy - Is calculated from individual energy inputs. Note that the primary equivalent of direct electricity consumption includes losses in electricity generation and distribution.

Energy use may be entered in physical units (e.g., billion cubic feet of natural gas) or primary units (trillion Btu). The exception is electricity use, which has to be entered as site energy consumption (either in billion kwh or trillion btu). Physical units is the default value for all energy use. To change to trillion btu, select the appropriate fuel (electricity, natural gas, etc.) and then select either physical units or trillion Btu from the pull down list.

Environmental

Environmental impacts of your new technology can generally be divided into impacts that are a direct result of energy savings and non-energy-savings-related emissions impacts. The energy-savings-related environmental emissions are calculated automatically by the spreadsheet from the energy savings (and fuel substitutions or use of biomass) and typical emissions factors for fossil fuels and electricity use. If your technology results in changes to consumption of feedstocks, biomass, wastes, or other fuels then you will need to enter appropriate emission factors for those fuels on the supplementary table.

Please provide estimates for non-combustion related emissions and non-energy-related waste production associated with the new and conventional technologies.

Other Greenhouse Emissions Displaced
Estimate of the amount of greenhouse emissions other than CO2, Nox, and VOCs if germane to your technology. These could include methane, perflourocarbons, or other gases. Identify which gas in the Description sheet.

Cost and Lifetime

Please provide rough estimates of the initial capital cost, operation and maintenance costs, non-energy variable costs, and lifetime associated with your technology new and old on a per-unit basis. Non-energy costs should include improvements to productivity that may not be captured in the O&M costs.

Market Inputs

To determine the potential impact of the new technology as it becomes adopted, it is necessary to estimate the total market for the technology, reduce that to the likely actual market, and estimate when and the rate at which the new technology will penetrate the market.

Total Market

The next step in projecting the overall potential impact of your technology is to identify the total market: the number of units that perform the same task as your proposed technology. Only the domestic U.S. market should be included. World market and export potential are important factors which may be considered separately, but this analysis is to estimate domestic energy and emissions reduction impacts.

Number of Installed Units in US Market
Please define that market as narrowly as possible: i.e. the smallest group of applications that covers all potential applications that you may have some data for. You may base your estimate on the energy use of the state-of-the-art technology and the energy use data provided in this package. Other potential data sources include OIT's Energy and Environmental Profile for the relevant industry, EIA's MECS data, or industry sources. Please provide a citation for the number of units in the comments section. Please also indicate for which year the data that you provided applies.

Annual Market Growth Rate
This should be based on an EIA or industry growth projection for the relevant industry. Please provide a citation for the growth rate in the comments section.

Market Share

Market share is a function of the potential accessible market share and the likely market share.

Potential Accessible Market Share
Please estimate the accessible market: the market that the new technology could reasonably access given technical, cost, and other limitations of the technology. For example, certain technologies may only be applicable to a certain scale of plant, certain temperature-range processes, certain types of existing equipment or subsystems, or only certain segments of the industry.

Likely Market Share
In some instances, in addition to technical and cost factors, your technology may compete with other new technology approaches, or with other companies for the market. Please estimate the likely market share. Use current market share information or base your estimate market share on the basis of the number of competitors in the market, assuming they are using different technologies not resulting from this project. This is different than the possibility of "copycats" which should not be considered as competing. That is, if others adopt essentially the same, or slightly modified, technology due to this new technology, that adoption was triggered by the project being described and that project should be "credited" with causing that trend. This is potentially the case for techniques where the intellectual property cannot be, or is not, protected and becomes general knowledge throughout the industry.

Savings Attributed to Program

In some instances a program may be developing a technology in conjunction with another OIT, EERE, or DOE program. If this is the case, please provide an estimate of the percentage of savings that is attributed to the program. The attribution percentage should be similar to the percentage of federal funds provided to the project by the program. A default value of 100% has been entered in the model.

Market Penetration

To understand how rapidly the potential impact of the technology may be felt, the market penetration of the technology must be projected. This is based on two estimates, the technology development and commercialization timeline, and the market penetration curve.

Technology Development & Commercialization Timeline
The commercial introduction of a technology normally occurs after a significant demonstration or operating prototype and after an adequate test and evaluation period along with allowances for the beginnings of production, dissemination of information, initial marketing and sales or other "start up" factors. To capture this lengthy

process, please indicate the timeline for developing and introducing the technology into the market. This includes the years for when an initial prototype, refined prototype, and commercial prototype of the technology has or will be completed and the year when the technology will be commercially introduced. An initial prototype is the first prototype of the technology. A refined prototype represents changes to the initial prototype but not a commercially scaled-up version.. A commercial prototype is commercial-scale version of the technology. Commercial introduction is when the first unit beyond the commercial prototype is operating. Prototype and commercial introduction years should be consistent with your technology development program plans. Please note that two values for a commercial introduction year are requested. One should reflect when the technology is projected to be introduced if the program proceeds as expected (With OIT case). The other should reflect when the technology would have entered the market if the program had not been involved (Without OIT case). If the technology would not have been commercially introduced without the program, then enter a year of 2050 for the Without OIT case. The difference in commercial introduction years for the With OIT and Without OIT cases is referred to as the acceleration period.

Market Penetration Curve (Technology Class)
New technologies normally penetrate a market following a familiar "s" curve, the lower end representing the above uncertainties overcome by "early adopters." The curve tails off at the far future where some may never adopt the new technology. Of importance is the major portion of the "s" curve where the new technology is penetrating the market and benefits are being reaped. The rate at which technologies penetrate their markets varies significantly: penetrations of heavy industrial technologies generally takes place over decades, while simple process or control changes can penetrate much more rapidly. The actual penetration rate varies due to many economic, environmental, competitive position, productivity, regulatory, and other factors.

To assist you, a large volume of actual penetration rates of past and present technologies were analyzed, normalized, and grouped into five classes based on a number of characteristics and criteria. In Table I, circle the class (column) which you believe your technology best fits for each characteristic (row). Note that the characteristics (rows) are relatively independent and a given technology will likely fit best in different classes for different characteristics. By examining the pattern, however, one can, based on best judgment and experience, select the most likely class (rate) at which the new technology may penetrate the market. This may be a "subjective average" of the circled best fits, or it may be that one or two characteristics are believed to so dominate future adoption decisions that a particular class of penetration rate is justified. There also may be "windows of opportunity" where significant replacements of existing equipment may be expected to occur at some point in the future for other reasons. The proposer should insert into the spread sheet the class of penetration rate believed most likely, all things considered, and provide a narrative of the rationale for selection if not obvious from Table I.

For additional assistance, Table II shows actual technologies and the class of their historical penetration rates. Comparison of the new technology, by analogy or similarity, with these examples provides additional insight into selecting the appropriate penetration rate that might be expected for the new technology.

Expenditure Inputs

The benefits of a project need to be assessed relative to its costs. Please provide information on the level of funding for the project by EERE, other government agencies, and the private sector for the appropriate years. This should be entered under the "With OIT" area on the expenditure inputs sheet. Nominal dollar values should be entered.

Background

Please provide calculations that support the information entered into the unit inputs and market inputs sheets.

Impact Projections

The spreadsheet, based on the unit performance, market size, commercial introduction, acceleration period, and penetration rate class, calculates the estimated benefits which the new technology may bring to the industry and to the nation. Annual, cumulative and lifetime benefits are calculated for energy savings, cost savings, and emission reductions.

Table I. Selecting the Market Penetration Rate Class

Characteristic	A	B	C	D	E
Time to Saturation (ts)	5 yrs	10 yrs	20 yrs	40 yrs	>40 yrs
Technology Factors					
Payback* discretionary	<<1 yrs	<1 yrs	1-3 yrs	3-5 yrs	>5 yrs
Payback* non-discretionary	<<1 yrs	< 1 yrs	1-2 yrs	2-3 yrs	>3 yrs
Equipment life	<5 yrs	5-15 yrs	15-25 yrs	25-40 yrs	>40 yrs
Equipment replacement	None	Minor	Unit operation	Plant section	Entire plant
Impact on product quality	++	++	++	+	O / -
Impact on plant productivity	++	++	++	+	O / -
Technology experience	New to US only	New to US only	New to industry	New	New
Industry Factors					
Growth (%p.a.)	>5%	>5%	2-5%	1-2%	<1%
Attitude to risk	open	open	cautious	conservative	averse
External Factors	forcing	forcing	driving	none	none
Gov't regulation					
Other					

* Payback is defined as capital outlay for new technology divided by savings before taxes and depreciation. In the case of Discretionary investments (i.e. replacements of existing equipment before the end of its economic life), capital outlay is total cost of new technology. In the case of non-discretionary investments (i.e. replacements of existing equipment at the end of its economic life and new installations), capital is the capital cost of the new technology - capital cost of current technology.

Table II. Examples

Class	A	B	C	D	E
Aluminum		Treatment of used cathode liners	Strip casting, VOC incinerators		
Chemicals	New series of dehydrogenation catalyst (incremental change)	CFCs -> HCFCs, incrementally improved catalysts, membrane-baed chlor-alkali	Polypropylene catalysts, solvent to water-based paints, PPE-based AN	Synthetic rubber & fibers	
Forest Products			Impulse drying, de-inking of waste newspaper	Kraft pulping, continuous paper machines	
Glass		Lubbers glass blowing, Pilkington float glass	Particulate control, regenerative melters, oxygenase in glass furnaces		
Metals Casting	New shop floor practice				
Petroleum	New series HDS catalysts	Alkylation gasoline	Thermal cracking, catalytic cracking	Residue gasification, flexicoking	
Steel	Improved EAF operating practice (e.g. modify electric/ burner heating cycle to minimize dust generation)	BOF steel making	Oxyfuel burners for steel, Level II reheat furnace controls, Continuous casting, particulate control on EAF, Hightop pressure blast furnace	Open hearth technology, EAF technology	
Other		Advanced refrigerator compressors, oxygen flash copper smelting, solvent extraction with liquid ion exchange	Fluegas desulfurization (coal-fired utilities), low Nox industrial burners, industrial gas turbines, ore beneficiation		Dry-kiln cement, industrial ceramic recuperators Industrial heat pumps

Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs

FY 2004 Budget Request

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

(Appendix D Only)

Prepared by the

National Renewable Energy Laboratory

April 2004 NREL/TP-620-36404

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

Final Documentation Report for

FY2004 GPRA Metrics

Subtask 5

Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared for:

National Renewable Energy Laboratory
and
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Prepared by:

Princeton Energy Resources International

February 2003

Table of Contents

1. **Program Chapters**
    a. Overview
    b. Solar Programs
        i. Solar Buildings
        ii. Photovoltaics
    c. Biomass
    d. Wind
    e. Geothermal
    f. Distributed Energy Resources

2. **Appendices**
    a. Market Segmentation
    b. Overview of Modeling Framework
    c. Green Power Market Model

Overview of FY 2004 Benefits Analysis

The Office of Energy Efficiency and Renewable Energy's (EERE) Renewable and Distributed Energy R&D programs manage research in two broad areas: 1) Energy Supply Technologies; and 2) Electricity Delivery. Several different approaches are required to estimate the benefits of this wide array of programs. The analytical approaches used for FY 2004 are documented in this report, as are the results of these analyses. This chapter provides a broad overview of the approaches taken for each of the two EERE research areas. Greater detail for each EERE Renewable and Distributed Energy program is provided later in this report in program-specific discussions.

Energy Supply Technology Programs

EERE manages six renewable energy technology programs – photovoltaics (PV), biopower, wind, geothermal, solar buildings and hydropower. The five electricity-generating technologies (not including hydropower which is not part of this analysis) were analyzed within the segmentation framework shown in Figure 1. The Solar Buildings program benefits, although shown in Figure 1, were analyzed using a different approach because solar building technologies produce thermal energy and not electricity. This different approach is described later in this report in the Solar Programs chapter. The benefits of the Distributed Energy and Electric Reliability (DEER) program are also estimated as part of the framework shown in Figure 1.

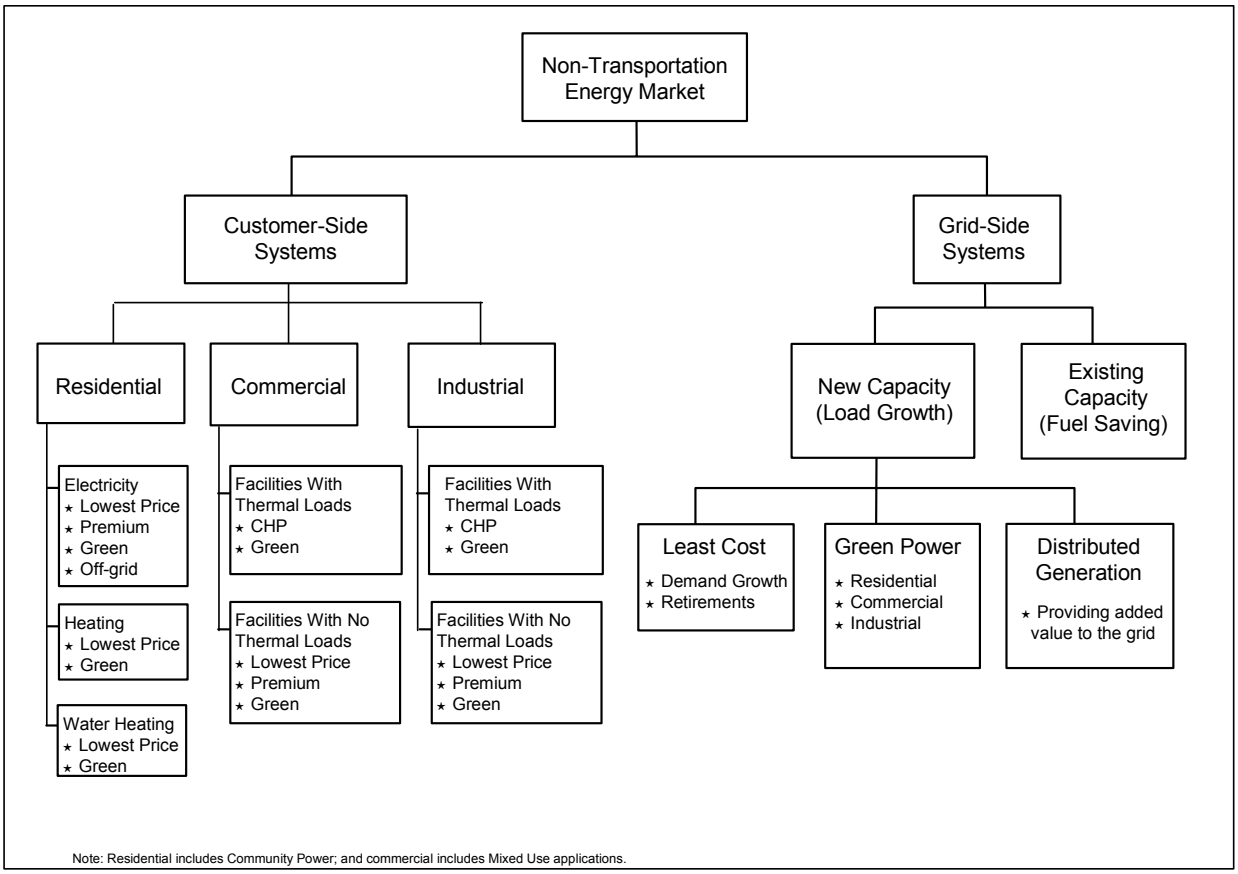

Figure 1 – Market Segmentation for EERE's Renewable and Distributed Energy Programs' Benefits Analysis

The U.S. non-transportation energy market was segmented into: 1) Grid-Side Systems -- systems that are on the grid side of the meter, and owned by utilities or other power suppliers; and 2) Customer-Side Systems -- systems installed at customer locations on the customer side of the meter. Figure 2 shows how the various market segments were analyzed to calculate EERE's Renewable and Distributed Energy programs benefits.

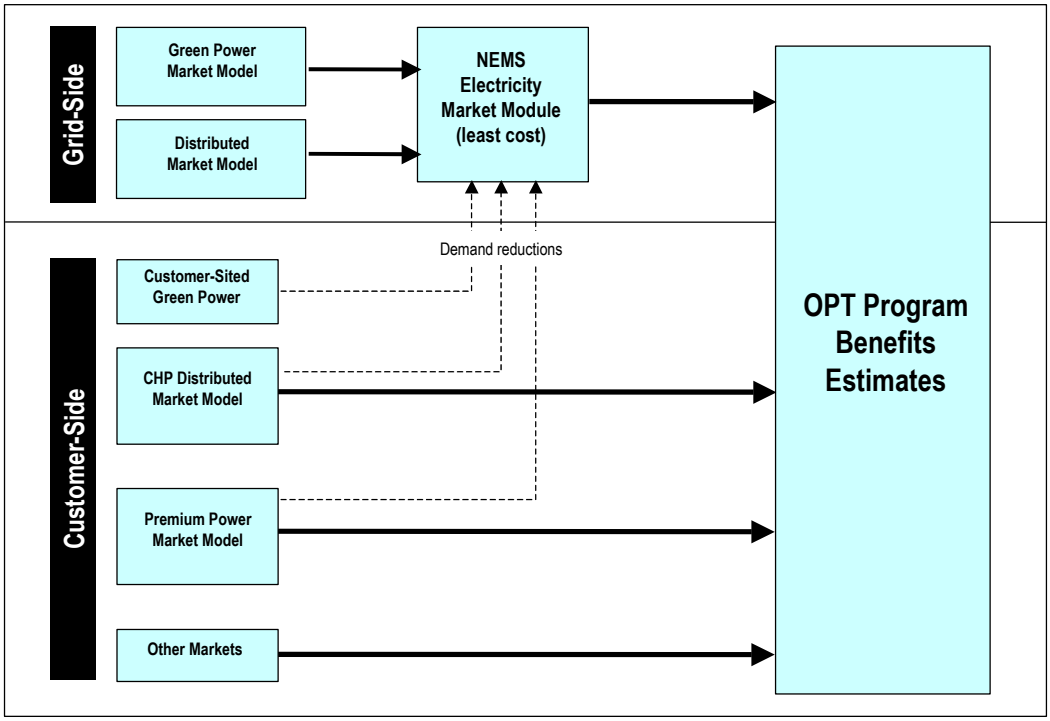

Figure 2 - Analysis Framework for Estimating EERE's Renewable and Distributed Energy Programs Benefits

Grid-Side Market Segment

Figure 3 shows a detailed breakout of the Grid-Side Market segment. The five electricity-generating technologies fall into three primary market segments as follows:

Least-Cost Power

The least cost segment refers to the bulk power market, which has traditionally been the province of the regulated utility industry. In analyzing this segment, growing demand and the need to replace retiring plants is met by projecting the installation of a mixture of power plants. The mixture chosen to meet this growing demand may have many attributes, but the primary one is that the lowest-cost option is typically selected through a detailed analysis process that compares all available options, both renewable and conventional.

Although this segment of the market may in the future be implemented through competitive bidding into a power pool or through bilateral contracts between suppliers and consumers, it will still be likely that the lowest cost option will capture the largest portion of the market. This segment of the market also includes renewables that could be installed to supply electricity at a

cost lower than the variable operating cost of existing capacity (commonly referred to as the fuel-saving mode).

For EERE's Renewable and Distributed Energy programs analyses, the National Energy Modeling System (NEMS) is used to estimate future generating technology use in this market segment. This is the same analysis approach as that used by EIA for the Annual Energy Outlook, and EIA's Annual Energy Outlook (AEO) 2002 reference case is used as the baseline for this analysis. OnLocation, Inc. (OnLocation) runs NEMS for EERE, making significant modifications to EIA's technology assumptions and EIA's approaches to characterizing renewables' ability to compete in the competitive market creating NEMS-GPRA04. These changes are believed to characterize EERE's renewable technologies more accurately. An important change, which is common to all five generating technologies, is the use of technology data from the EPRI/DOE *Renewable Energy Technology Characterizations* report, or program updates to this report. The difference from the NEMS-GPRA04 run and the baseline AEO02 run represents the program's expected impact on the market.

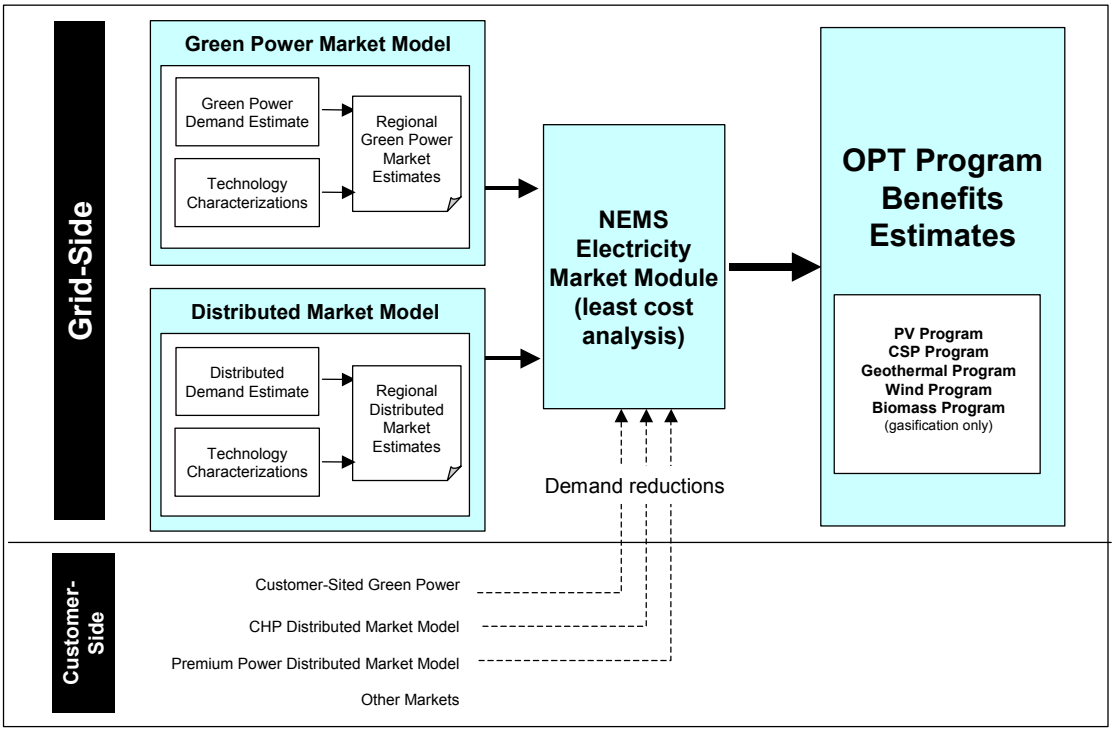

Figure 3 - Analysis Detail for Grid-Side Market Benefits Estimates

A variety of technology-specific changes have also been made. These changes had the greatest impact on the wind and geothermal technology projections, resulting in increased penetration of each when compared to the AEO projections. The technology-specific changes made are described in this report in the appropriate program discussion in later chapters.

Green Power

EERE sponsored the development of a Green Power Market Model (GPMM) by Princeton Energy Resources International (PERI). In this model, the projected green power market size is

allocated to the various EERE renewable technologies using an algorithm similar to that, which is used by NEMS. The allocation is performed using a logit function approach to calculating market sharing. The logit function uses the various competing technologies' levelized cost of energy to determine which will be chosen by green power suppliers in a particular region to meet the demand for green power in that region.

The size and timing of the overall green market are key assumptions made for this analysis. The set of assumptions for electricity market restructuring from the *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy*, a recent report by Blair Swezey et al. completed for the National Renewable Energy Laboratory (NREL), continued to be used for this year's analysis. (4) These assumptions include the dates for initiation of market restructuring as well as the assumed green power penetration rates, a change in the time periods tracked in the analysis, and a new method for calculating funds from program participants.

Several changes from last year's assumptions have been included this year. New technology characterizations for wind, class 4 and 6 data averaged, and CSP, trough and power tower data, were taken from program revisions to the *Renewable Energy Technology Characterizations*. Additionally, the regional economic sectors' energy consumption and prices were updated according to the new Energy Information Administration's (EIA) assumptions for the *Annual Energy Outlook 2002* (AEO 2002). Finally, PERI included both additions and subtractions to the green capacity values for the Million Solar Roofs (MSR) capacity additions, and EIA "floors" builds.

A detailed discussion of this analysis and its results can be found in Appendix C. The results of the GPMM runs were explicitly included in the NEMS runs by specifying the green capacity as planned capacity. The effect of this exogenous determination is to reduce future levels of new demand such that when NEMS is run the projections of new conventional capacity and new least-cost renewables are lower than in the base case where no green capacity is explicitly included.

Distributed Generation

Grid-Side Distributed Generation Market benefits are realized when technologies are strategically installed in locations where they can provide benefits to the distribution system beyond the basic commodity supply benefits. An example of such a benefit is the ability to defer, or potentially avoid, a distribution system upgrade. This Distributed Generation Market has yet to materialize for renewables, although a number of EERE programs are working to facilitate renewable penetration into this sub-segment.

Customer-Side Market Segment

Figure 4 shows a detailed breakout of the Customer-Side Market segment.

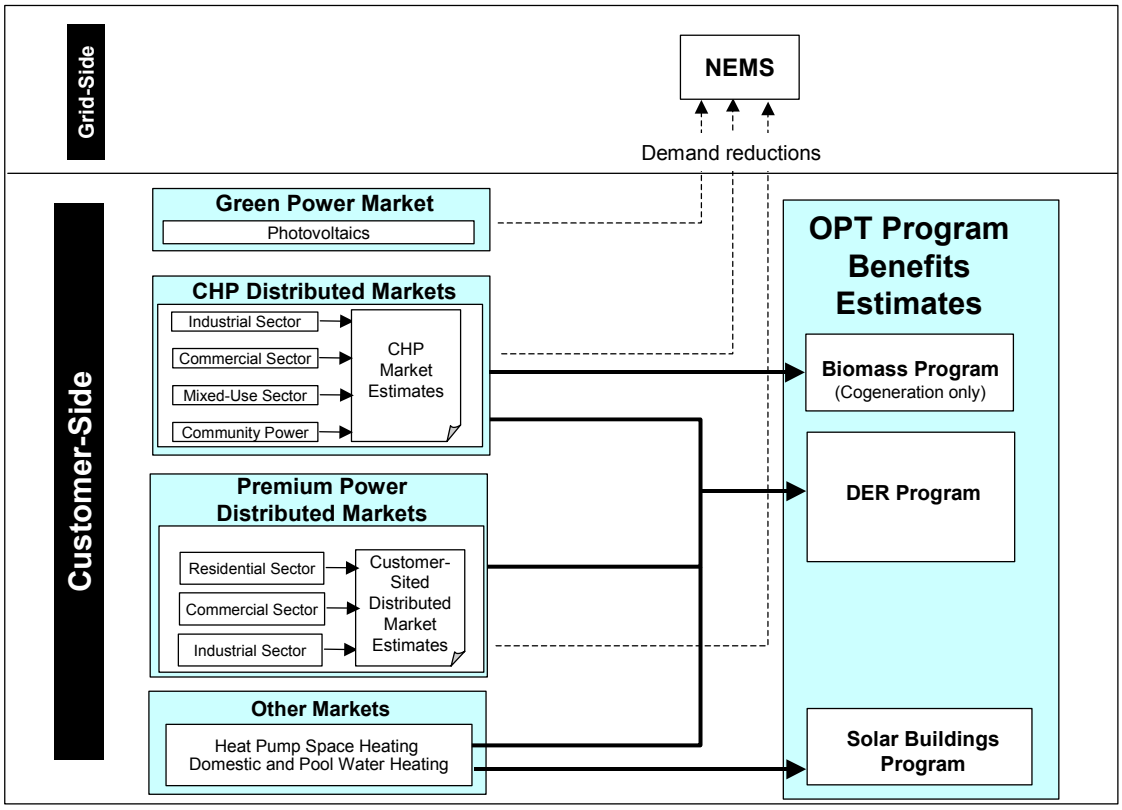

Figure 4 - Analysis Detail for Customer-Side Benefits Estimates.

Green Power

Photovoltaics (PV) was the sole option examined for residential and commercial customer-side green power installations. Although other renewable technologies may well be installed in the residential and commercial sub-segments in the future, PV appears to be at the moment the only technology with significant early market momentum, largely due to the Million Solar Roofs (MSR) program. There may also be small numbers of customer-sited PV systems that are not actually owned by the customer. The extent of PV penetration into the customer-sited market segment was projected to be very closely tied to the 2010 goal of the MSR program.

Overall, although customer-sited PV systems represented the vast majority of projected PV installations for the FY 2004 benefits analysis, customer-sited renewables accounted for only a small portion of all projected renewable penetration.

Combined Heat and Power

The Customer-Side Market segment also includes combined heat and power (CHP, or cogeneration) applications. In these applications, commercial and industrial facilities are equipped to produce both power and thermal energy. The DEER program's benefits are estimated by the NEMS for this market segment. Also estimated as part of the CHP market, biomass cogeneration in the industrial market sub-segment was the other customer-sited renewable technology analyzed. Biomass cogeneration is reported as part of the DEER benefits, and not in the biopower program's benefits totals. This application is particularly suitable to

pulp and paper mills, where a prevalence of free fuel, in the form of biomass waste, and the need for process heat makes cogeneration particularly attractive. This market opportunity for biopower increased rapidly in the 1980s with the enactment of PURPA, but as PURPA expired and sites with the greatest potential had been used, the market opportunity has leveled off. The Energy Information Administration (EIA) using NEMS projects only modest future expansion in this sub-segment. The other biopower technologies: direct-fired, and gasification-based generation are electricity-generating technologies and are handled under the grid-side market segment.

Premium Power Distributed

On the Customer-Side, there are opportunities for providing power in applications where the customer is willing to pay a premium for higher quality power, for power with higher reliability, or for power with greater certainty of future price stability. There is no projected penetration of renewable energy power technologies into this market segment for GPRA reporting. More-conventional technologies, using natural gas, were deemed more likely to be used for premium power applications for the foreseeable future. Although not modeled, it should be noted that some "conventional" DEER technologies could also meet the needs of this market.

Other Markets

Other Markets in the Customer-Side Market include markets for solar domestic hot water (SDHW) and solar pool heating (SPH) technologies. These two technologies comprise the Solar Buildings program and represent almost the entire end use for solar thermal collectors. Benefits are derived from the natural gas and electricity displaced that conventionally fuels these heating requirements.

Electricity Delivery Programs

The benefits of the EERE electricity delivery programs cannot be estimated within the framework described above, and must be estimated using various techniques developed by program personnel or their contractors. Many of the programs formerly reported separately under Electricity Delivery Programs, such as High Temperature Superconductivity (HTS), Renewable Energy Production Incentive (REPI), Transmission reliability, Energy Storage, Distribution and Interconnection, and Distributed Generation, have been incorporated into the new DEER program. As such, the benefits of these programs are reported under the DEER program. DEER benefits are calculated from the CHP capacity and generation additions modeled in NEMS. Additionally, the Hydrogen program does not receive any credit for hydrogen fuel cell penetration expected in the CHP market. This capacity is credited to the DEER program.

Table 1 summarizes the current status of programs formerly reported under the Electricity Delivery Programs, and the approaches now used to characterize their benefits for this analysis.

Table 1. Approaches Used For Prior Benefits Estimates of EERE Electricity Delivery Programs.

Program Element	Benefits Estimation Approach
Hydrogen	For FY2004, the program's benefit analysis was done by characterizations from OTT. In year's past, OPT had PERI do an off-line analysis of fuel cell and electric cars, with a portion of the benefits given to the hydrogen program. A market penetration model was developed to estimate the penetration of fuel cell-powered passenger cars and SUVs into both high-value and ZEV mandate markets. In the FY2003 analysis, the Hydrogen program claimed a portion of the benefits of the DER program from 2015 to 2030, with the reasoning that hydrogen technologies are expected to penetrate in this market segment in the form of hydrogen-fueled fuel cells. However, in the FY2004, all hydrogen fuel cell capacity penetration is credited to the DEER program.
High Temperature Superconductivity (HTS), Renewable Energy Production Incentive (REPI), Transmission reliability, Energy Storage, Distribution and Interconnection, and Distributed Generation	These programs are now included in the DEER program. All benefits are characterized in the DEER program chapter.

Program Summary Tables

A summary of the estimated benefits from the Energy Supply Technology Programs is presented in Table 2. The table shows capacity projections which are cumulative, but that have been calculated against the *AEO 2002* baseline. In other words, these results do not include the installed capacity base as of the end of 2002 or the capacity projected in the *AEO 2002*. These capacity projections form the basis for the estimation of the various GPRA metrics for the five generating technology programs: Photovoltaics, Biomass, Wind, Geothermal and DEER.

Annual electricity production for each technology was estimated in NEMS from these capacity projections, and from appropriate capacity factors for each technology. From the annual energy production, primary energy displacement, energy cost savings, carbon displacement, NOx displacement, and SOx displacement were calculated. The *GPRA Data Call: Fiscal Year 2004* guidance document (Appendix D) was used as the source for information on fuel mix displaced, emissions factors, average grid heat rates, fuel prices, etc.

Table 2. Summary of Benefits Estimates for Energy Supply Technology Programs

	2005	2010	2015	2020	2025	2030
Cumulative Capacity Installed above AEO 2002 Baseline (thousands of MW)						
Photovoltaics	0.20	0.95	2.95	4.95	7.00	9.00
Biopower	0.05	0.19	0.37	0.55	0.75	0.90
Wind	1.50	4.65	19.2	33.8	48.5	63.0
Geothermal	0.05	1.80	4.20	6.65	9.10	11.6
Distributed Energy and Electric Reliability	2.30	7.45	16.3	25.0	33.8	42.6
Annual Energy Production (billions of kilowatt-hours/year)						
Photovoltaics	0.35	1.75	5.30	8.85	12.4	16.0
Biopower[1]	0.32	1.30	2.45	3.65	4.85	6.05
Wind	8.05	22.8	85.5	148	211	273
Geothermal	0.40	14.6	34.2	54.0	73.5	93.0
Distributed Energy and Electric Reliability	16.7	54.0	117	180	243	307

1) Biomass Direct Electricity Displaced does not include generation from cofiring capacity, as this is not new capacity, but rather is considered to be a fuel switch for existing or planned capacity, which is addressed as fossil energy displacement.

Table 2. Summary of Benefits Analyses for Energy Supply Technology Programs (cont.)

	2005	2010	2015	2020	2025	2030
Annual Primary Energy Displacement (Trillion Btu/year)						
Total Solar Program	4.00	23.0	66.7	113	164	219
Solar Buildings	0.30	7.45	22.9	42.7	66.0	92.0
Photovoltaics	3.70	15.6	43.8	70.0	98.0	127
Biopower[2]	3.55	12.2	21.5	30.3	40.2	50.0
Wind	59.0	157	655	1,115	1,610	2,105
Geothermal	4.25	132	283	425	580	735
Distributed Energy and Electric Reliability	177	294	550	775	1,045	1,315
Annual Energy Cost Savings (billions of dollars/year)						
Total Solar Program	10.0	52.7	176	322	494	696
Solar Buildings	0.75	17.1	60.5	122	199	294
Photovoltaics	9.20	35.7	116	200	296	403
Biopower	-1.65	-13.9	-18.1	-14.8	-8.05	5.15
Wind	146	359	1,725	3,180	4,840	6,695
Geothermal	10.6	301	745	1,215	1,745	2,340
Distributed Energy and Electric Reliability	0.50	1.55	3.35	5.25	7.05	8.80
Annual Carbon Displacement (million metric tons of carbon equivalent/year)						
Total Solar Program	0.08	0.48	1.31	2.20	3.20	4.25
Solar Buildings	0.01	0.16	0.46	0.85	1.30	1.80
Photovoltaics	0.07	0.32	0.85	1.35	1.90	2.45
Biopower	0.07	0.25	0.43	0.60	0.80	0.95
Wind	1.10	3.20	13.0	21.7	31.3	40.9
Geothermal	0.08	2.70	5.60	8.25	11.3	14.3
Distributed Energy and Electric Reliability	2.60	7.70	14.4	20.1	27.1	34.1

2) Biopower benefits are cited in terms of Fossil Fuel Energy Displaced because biomass is, itself, a primary energy source.

Table 2. Summary of Benefits Analyses for Energy Supply Technology Programs (cont.)

	2005	2010	2015	2020	2025	2030
Annual SO_x Displacement (millions of metric tons/year)						
Total Solar Program	0.001	0.007	0.019	0.030	0.043	0.057
Solar Buildings	0.000	0.002	0.007	0.011	0.017	0.024
Photovoltaics	0.001	0.005	0.012	0.018	0.026	0.033
Biopower	0.001	0.003	0.004	0.005	0.007	0.009
Wind	0.014	0.049	0.185	0.292	0.421	0.551
Geothermal	0.001	0.041	0.080	0.111	0.152	0.193
Distributed Energy and Electric Reliability	0.050	0.181	0.337	0.469	0.633	0.796
Annual NO_x Displacement (millions of metric tons/year)						
Total Solar Program	0.001	0.004	0.012	0.019	0.028	0.038
Solar Buildings	0.000	0.001	0.004	0.007	0.011	0.016
Photovoltaics	0.001	0.003	0.008	0.012	0.017	0.022
Biopower	0.000	0.002	0.003	0.004	0.005	0.006
Wind	0.010	0.029	0.117	0.192	0.277	0.362
Geothermal	0.001	0.025	0.050	0.073	0.100	0.126
Distributed Energy and Electric Reliability	0.024	0.077	0.142	0.198	0.266	0.335

FY2004 GPRA METRICS
SOLAR PROGRAM
SUB-PROGRAM: SOLAR BUILDINGS

Table 1. Summary of Solar Buildings Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Thousands of systems above Baseline)						
DHW	3.50	202	764	1,526	2,365	3,277
Pool Heating	3.50	40.9	93	159	243	350
Total (may not add due to rounding)	7.00	243	857	1,685	2,608	3,627
Annual Benefits						
Energy Displaced (TBtu)	0.30	7.45	22.9	42.7	66.0	92.0
Energy Cost Savings (millions of 2000 $)	0.75	17.1	60.5	122	199	294
Carbon Displaced (MMCTE)	0.01	0.16	0.46	0.85	1.30	1.80

Market Segments

The solar buildings program includes technologies for solar domestic hot water (SDHW) and solar pool heating (SPH) in residential and commercial buildings. According to EIA data,[1] SPH is the largest end use for solar thermal collectors, representing 95% of the total square feet shipped in 1999. SDHW accounted for nearly all the rest of the market, with only 0.5% for other uses such as space heating. The residential market accounts for more than 90% of each of these end uses. The FY2004 GPRA projections differ from those of FY2003 by including only market quantities and impacts due to DOE programs; specifically, they include only the low-cost polymer solar domestic water heater and the solar pool heater produced in colors other than black to allow wider architectural acceptance. Conventional SDHW and black SPH systems are counted in the baseline. As discussed below, the SDHW is assumed to compete with electric water heating, and the SPH competes with natural gas.

Princeton Energy Resources International (PERI) performed this exogenous model with the resulting penetration reported to OnLocation for inclusion in the NEMS baseline (AEO02) and program (GPRA-NEMS04) runs. OnLocation reduced the results of exogenous models for all programs by 30% across the board as a way of conservatively accounting for likely economic interactions within markets that often cannot be specifically identified without fuller modeling. The unit penetrations reported in Table 1, and the resulting benefits, represent this 30% reduction from the PERI modeled values, which are presented in the remainder of this section.

System Definition and Economics

Solar Domestic Hot Water

Typical residential SDHW systems have collector area ranging from 40 to 80 square feet, depending on geographic location, and costs ranging from $1,800 to $3,600.[2,3] Other studies show similar costs for conventional solar systems, although thermosiphon or integral collector storage (ICS) systems are available for about half that cost in package units with perhaps 20 square feet or less of collector area. The SWAP program in Florida recently installed 24 to 32 square foot direct pumped or ICS systems in low-income homes for $1400 to $1750.[4,5] A detailed analysis of a "traditional" ICS system found a total installed cost of $2800.[6] Note that 80% of solar collector sales (by square feet) went to five states: Florida (44%), California (25%), Arizona (5%), Hawaii (3%), and Nevada (3%).[7] Because most installations are in warmer climates, for this GPRA analysis it is reasonable to assume a cost of $3000 for an average SDHW system using 50 square feet of conventional collector technology.

The analysis assumes the introduction in 2005 of a low-cost polymer collector, which the Solar Buildings Program began developing in 1998 and which is now in prototype testing by two manufacturers. Because this is a storage-type collector, applications would be in milder climates. Existing flat-plate collectors cost about $17 per square foot[8], or about $42 per square foot after manufacturer profit and markups by the distributor and dealer/contractor, and the storage tank and other equipment add an additional $1200 or more.[9] The goal of the DOE program is to reduce the hardware and installation cost by half, using a lower-cost collector and storage tank and simpler installation techniques. Excluding marketing costs, it is estimated that the new system could be sold for $1000. Marketing for the conventional system, sold on an individual basis, is estimated at $800.[6] If the new system could be sold on a mass basis to builders, the marketing cost could be reduced greatly, by perhaps half for the overall market, giving a total cost of $1500 per unit, ranging down to $1000 for large purchases by builders.

For this GPRA analysis, the energy saved by the SDHW system is assumed to be 2,752 kWh per year. Because the warmer areas of the country have lower hot water use per capita and warmer supply water temperature, the actual water-heating load across the country is not uniform. This number corresponds to the national-average site electricity savings calculated by ADL, averaging the cases of high and medium water draw.[10] The ADL analysis was based on simulation model runs for five cities corresponding to the five DOE climate zones, although their method for determining the national average was not disclosed. A recent report by Antares, using data apparently based on the experience of the Sacramento Municipal Utility District, assumes an energy savings of 2,544 kWh per year, 8% lower than that used here.[11]

The solar fraction of an SDHW system is the percentage of water heating energy supplied by solar energy. For a typical SDHW system, the solar fraction is 60%, with the remaining 40% supplied by an auxiliary system, usually an electric heater. System cost decreases if the solar fraction drops below 50% and increases greatly if it is pushed to 80% or higher. The energy savings of 2,752 kWh corresponds to the 60% solar energy supplied by an SDHW system in a household with an average water heating load of 4,583 kWh, typical of a moderate U.S. climate.

Based on this annual energy savings and a residential electricity cost of $0.083/kWh in 2000 (AEO 2002, Table A3), the energy cost savings is $228 per year, giving a simple payback of 13 years for a $3000 current system. However, including an O&M cost for the solar system of $30 annually (based on maintenance once each three years)[12] raises the simple payback to 15 years, a number approaching the system lifetime of 15-30 years. The payback period decreases, however, in states of high electricity cost; for example, above $0.12/kWh (as in much of California or in Hawaii[13]) the payback is less than 10 years, with O&M included. For the polymer system, assuming an installed cost of $1400 per unit, the payback is cut in half, from 15 to 7.5 years, or only 5 years if marketing costs are minimal due to mass purchase.

In comparison with a gas water heater of 60% efficiency, the annual energy savings is $120 at a gas price of $7.64/MMBtu (AEO 2002, Table A3), making the payback greater than 30 years for the current SDHW system. Accordingly, the SDHW is not expected to compete well with natural gas. However, as Antares points out, recent rates of large California utilities are in the range of $16/MMBtu,[11] bringing the payback down to 14 years for a current system and similarly reduced for the polymer SDHW, comparable to the electric case. Nevertheless, in this GPRA analysis, which is based on EIA national energy price projections, only displacement of electric water heaters by SDHW is considered.

Solar Pool Heating

The SPH system consists of an unglazed solar collector, usually plastic. Water is circulated using the pool's existing pump, and the pool provides its own thermal storage. A "rule of thumb" is that the area of an SPH collector area must equal about 50 to 100% of the pool area to provide all the pool water heating requirements, and using a pool cover will reduce the SPH area required, so it is reasonable to assume an average of 75%.[14] For the average residential pool size of 576 square feet, as quoted by DOE's Reduce Swimming Pool Energy Costs (RSPEC) program, the required collector size is 432 square feet, the number used in the FY2003 and earlier GPRA analyses. However, the Solar Energy Industries Association (SEIA) states that the average SPH is 300 square feet, which will be used here.[15]

The present analysis assumes a typical residential SPH system cost of $3500, or just under $12 per square foot, based on SEIA data.[15] The FY2003 and earlier GPRA analyses assumed $4000. Note that according to EIA, the average price of the collector alone in 1999 was $2.08 per square foot, presumably wholesale.[8] This would imply that the final cost, including dealer mark-up and installation, is more than five times the collector price reported by EIA.

A typical SPH lifetime is 10 to 15 years[14] for a plastic or rubber collector, with the main problem being degradation by ultraviolet light. Because the system is so simple, there is little or no maintenance beyond that normally given to the pool's circulating system. Accordingly, this analysis assumes zero O&M costs for the SPH.[16]

Energy performance certifications of unglazed solar pool heating panels indicate that they produce an average of 1000 Btu per square foot per day, according to the Florida Solar Energy Center and the Solar Rating and Certification Corporation.[15,17] Assuming, as does SEIA, a very

conservative use of five months per year, the 300 square foot SPH produces 150,0000 Btu/ft^2/year, or a total of 45 MMBtu/yr of thermal energy.

The energy displacement achieved was checked by estimating the solar resource available in a highly favorable location, Miami in this analysis. In that location, a latitude tilt collector receives 177 kWh/ft^2 annually of solar insolation, which is equivalent to 604,278 Btu/ft^2 annually. For six months of operation per year (during shoulder months), it was assumed that the solar insolation was 65% of the total annual. Combining this 65% factor with an annual average efficiency of 70%, one calculates a pool heating demand displacement of 275,000 Btu/ft^2/yr. This is nearly twice the average estimate above.

This GPRA analysis will use the conservative estimate of 150,000 Btu/ft^2/yr. Assuming that gas is displaced and that the gas burner would average an efficiency of 75%, the solar pool collector is assumed to displace 200,000Btu/ft^2/yr. Finally, with an average collector size of 300 ft^2, the annual displacement of primary energy is estimated to be 60 MMBtu (600 therms) per pool. At a natural gas price of $7.64/MMBtu (AEO 2002, Table A3), this yields a payback of 7.6 years. Note that GPRA analyses for FY2003 and earlier assumed a much larger energy displacement of 1600 therms for a somewhat larger system of 432 ft^2.

In more favorable locations, the payback period would be shorter, about 4 years or less, making the SPH quite attractive. SEIA states that the payback is routinely two to three years. The FEMP program reports that SPH paybacks are frequently 2 to 4 years.[18]

The relatively static nature in prices of residential electricity and natural gas to 2030, to $0.0774/kWh and $7.22/MMBtu, respectively, will keep paybacks in this same range for future installations. However, local price increases will reduce the payback period.

The DOE program will develop SPH collector material by 2005 that can be made in various colors other than black, increasing the potential market by allowing greater architectural choices, while maintaining performance and cost.

This analysis does not consider non-residential pools, for which there are certainly some solar applications. For example, *Solar Today* mentions recent installations in the Bahamas and Mexico.[19] According to EIA[1], only 10% of the low-temperature collector shipments in 1997 went to non-residential markets, so their impact on national energy savings is small. The size of these commercial or municipal systems can be 10,000 square feet or more, raising questions of siting and pipe runs. Indoor pools in the U.S. now commonly use integrated heat pump systems for water heating, dehumidification, and air conditioning.

Installation Scenario

<u>Solar Domestic Hot Water</u>

According to EIA, a total of 400,000 square feet of solar collectors for medium-temperature liquids was shipped in 1999, excluding exports[1]. This corresponds to 6,200 to 10,000 SDHW units of common size (40 to 64 square feet). Based on data from the Solar Energy Industries

Association and assuming 50 square feet per system, the SDHW installations are estimated to be 8,448 units for 1998 and 8,000 units for 1999.[20]

In relative terms, this number is quite low. As ADL[21] points out, the overall target market of electric water heating installations is 4 million annually, of which 1.3 million are in single-family households. The ADL chart, "Proposed program goals are based on realistic market penetrations," goes on to state a target of 25,000 SDHW units for an unspecified year, presumably about 2003. EIA data[22] indicate that in 1983, the peak of the domestic SDHW market, the total square footage of medium-temperature collectors sold domestically was 9 million, corresponding to about 140,000 SDHW units (assuming 64 square feet each) or more. By the late 1980s more than a million units had been installed.[23]

The analysis described here assumes a baseline of 8,000 units per year of conventional SDHW sales. Although this number might be expected to grow somewhat over the years, it is also subject to decrease from competition with the polymer system, so for simplicity it is assumed constant. The polymer SDHW market was estimated by Antares[11] based on both new residential construction and retrofit primarily in 9 southern states, displacing electricity only. The fraction of the potential market taken by the polymer SDHW increases from an initial 4% in 2006 to 25% by 2010 and then a maximum of 50% by 2030. After a rapid start-up, annual growth of sales (annual increase in the number of installations in a given year when compared to the number of systems installed in the prior year) averages nearly 20% per year during 2010 - 2015 and finally declines to 2% per year by 2030. As a result, the annual installation rate follows an S-shaped curve. This GPRA scenario would achieve the ADL target level of 25,000 installations per year around 2007. The annual installations are estimated to rise to 228,000 by 2020 and 269,000 by 2030.

On a cumulative basis, the GPRA scenario reaches 500,000 installations by 2012, a strong contribution by solar thermal systems to the DOE Million Solar Roofs Program target. Cumulative installations exceed one million by 2020 and finally reach 4 million before 2030, or roughly 3-4% of single-family households.

This installation scenario is not directly tied to economics. As discussed above, the simple payback for the SDHW is in the range of 10-13 years. Previous renewable energy analyses for DOE[24] have used market penetration targets based on payback, ranging from 100% for a payback of 1 year or less down to zero penetration for a payback of 20 years or greater. For example, a payback of 3 years corresponds to 89%, 5 years to 66.5%, 7 years to 34%, 10 years to 15%, and 12 years to 9%. This implies that the projected market penetration is not unreasonable. Several programs and policies, none of which are modeled in this GPRA analysis, are likely to increase the market attractiveness of SDHW:

- The Database of State Incentives for Renewable Energy reports that 40 states are providing financial incentives for active solar water heating systems, up from the 30 states reported by EIA for 1996.[25,26] The impact of a tax credit is strong, as shown by the history of prior Federal and state tax credits in stimulating the solar water heating market from the mid-1970s to early 1980s. The Clinton Administration's proposed FY2000 Climate Change Budget originally included a 15% tax credit for rooftop solar

systems, with a maximum credit of $1,000 for solar water heating systems placed in service from 2000-2004. In the Bush Administration, pending energy bills in both the Senate and the House include a 15% residential solar energy tax credit for 5 years for solar thermal systems.[27]

- The Energy Efficient Mortgage allows the cost of improvements that reduce the energy bill to be included in the home mortgage, thereby offering a lower interest rate and longer term of repayment that could stimulate the market for SDHW systems on both new and existing homes.

- As a part of utility restructuring and regulatory changes, System Benefit Charges or Renewable Portfolio Standards may be used to promote energy efficiency and renewable energy technologies, including solar water heating, although it is unclear what form these programs might take. On the other hand, to the extent that utility restructuring reduces electricity rates, it makes SDHW less attractive.

Solar Pool Heating

RSPEC data indicate that there are 5.6 million residential pools in the U.S., of which half are assumed to be heated. The National Spa and Pool Institute (NSPI) reports 3.6 million in-ground residential pools. NSPI also reports annual sales of 172,000 new in-ground pools in 1998, up from 120,000 in 1994, or about 5% of the existing stock. In-ground pools are more likely to be heated than aboveground pools. These two sources, taken together, suggest that there are some 2 million heated residential pools in the U.S.

The *Solar Today* and *Home Energy* articles both state that as of the late 1990s there were 300,000 solar pool heaters installed in the U.S. According to both NSPI and EIA[1], 8.1 million square feet of pool collectors were sold in 1999, up from 7.2 million square feet in 1998. After subtracting exports and assuming an average system size of 300 square feet, this corresponds to 25,480 SPH systems in 1999, compared with 23,174 units for 1998. Based on Solar Energy Industries Association data, the installations for 2001 are estimated to be 33,000 units, or about one-fifth of the 180,000 pool heating systems sold annually.[15] This amounts to less than 2% of the total potential market on an annual basis, or about 20% of the annual new pool sales, suggesting that the SPH market is established but far from saturated. Data for the First Quarter 2002 showed a strong increase, indicating that for the preceding 12 months sales were nearly 35,000 units.[28]

As discussed above, simple paybacks for SPH systems are often four years or less. Therefore, it is reasonable to expect a high level of market penetration. From the method used in previous renewable energy analyses and mentioned above, market adoption rates could be in the range of 75% or higher.

The SPH baseline assumes that installations have a flat 5% escalation rate (compared to prior year levels), comparable to the current growth rate in number of pools. This is a conservative estimate, given that for the last 3 years growth has been an average of 10-15% annually. Starting from the annual installation rate of 38,000 in 2004, this leads to an annual installation level of

83,000 in 2020 and 135,000 in 2030. Cumulative installations from 2004 grow to 0.3 million in 2010, 1.0 million in 2020, and 2.1 million in 2030.

The DOE program expands the market from this baseline by developing SPH collectors in colors other than black. Some 42 million Americans now live in community associations, which have increased from 10,000 in 1970 to over 200,000 today. A 2000 survey of 13 solar contractors in Arizona, California, and Florida installing 3,800 SPH systems per year, 65% of which are in areas subject to community association restrictions, found that architectural controls by these associations often limit the use of roof-top solar collectors.[29] Greater choice of color would offer a better chance of approval. Assuming that half of the potential SPH market nationwide is in such areas and that half of those could be approved with a color choice, then the impact of the DOE program is to add about 25% to annual installations.

Accordingly, the DOE program portion of the total SPH market is assumed to start from the annual installation rate of 5,000 in 2005 and grow to an annual installation level of 21,000 in 2020 and 34,000 in 2030. Cumulative installations grow to 0.06 million in 2010, 0.2 million in 2020, and 0.5 million in 2030.

Benefits

For purposes of this analysis, SDHW displaces electricity and SPH displaces natural gas. Based on the projections of SDHW and SPH installations from PERI, reduced by 30% by OnLocation, the primary energy, emissions, cost, and fuel displaced are calculated using the assumptions stated in the *GPRA Data Call: Fiscal Year 2004* (Appendix D). Table 2 shows the results of this analysis.

Table 2. Solar Program Benefits from the Water and Pool Heating Program

	2005	2010	2015	2020	2025	2030
DHW (thousands of units)	3.50	202	764	1,526	2,365	3,277
Pool Heating (thousands of units)	3.50	40.9	93	159	243	350
Energy Cost Savings (millions of 2000 $)	0.75	17.1	60.5	122	199	294
Carbon Emissions Displaced (MMTCE/year)	0.01	0.16	0.46	0.85	1.30	1.80
SO_2 Displaced (MMTCE/year)	0.000	0.002	0.007	0.011	0.017	0.024
NO_x Displaced (MMTCE/year)	0.000	0.001	0.004	0.007	0.011	0.016
Primary Energy Displaced (trillion Btu/year)	0.30	7.45	22.9	42.7	66.0	92.0
Direct Electricity Displaced (billion kWh/year)	0.01	0.55	2.10	4.20	6.50	9.00
Natural Gas Displaced (billion cubic ft/yr)	0.21	2.40	5.45	9.35	14.3	20.7

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FY2004 GPRA METRICS
SOLAR PROGRAM
SUB-PROGRAM: PHOTOVOLTAICS

Table 1. Summary of Photovoltaic Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Least Cost	0.11	0.39	0.50	0.50	0.50	0.50
Green	0.07	0.07	0.23	0.39	0.48	0.60
Million Solar Roofs Initiative	0.02	0.50	2.25	4.10	6.00	7.90
Total (may not add due to rounding)	0.20	0.95	2.95	5.00	7.00	9.00
Annual Benefits						
Energy Displaced (TBtu)	3.70	15.6	43.8	70.0	98.0	127
Energy Cost Savings (millions of 2000 $)	9.20	35.7	116	200	296	403
Carbon Displaced (MMCTE)	0.07	0.32	0.85	1.35	1.90	2.45
Technology Indicators[1]						
Cost ($/kW)	2,930	2,150	2,055	1,615		
Capacity Factor (%)	20.8	20.7	20.7	20.7		
Levelized Cost of Energy (cents/kWh in constant 1997$)	20.4	12.8	12.0	9.55		

1) Based on weighting of Rooftop, Central Station Flat Plate and Central Station Concentrator technologies. *Renewable Energy Technology Characterization* data used for NEMS analysis (this report is currently being updated and the values may change).

Market Segments

In FY 2004 analysis, the photovoltaic (PV) program is expected to penetrate the market through three market segments: the green power market, the least cost power market, and the recently completed Million Solar Roofs (MSR) initiative.

- Green Power - PV has an important role to play in the future green power market. However, at present, because it is significantly more expensive to install than several other green power options, few utilities or energy service providers are likely to choose PV as a way of meeting customer demand for green power. The GPMM reflects this fact

by predicting very little penetration by PV in the green power market. Projections for total green market potential are taken from NREL, *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy* (NREL/TP-620-30101). The MSR projections, described below, have been added to the results of the GPMM for inclusion in NEMS. Also, there is an additional 250 MW of central station PV "floor" capacity that is "assumed by EIA to be installed for reasons in addition to least-cost electricity supply" between 2001 and 2020. This "floor" capacity addition is prorated for 2004 to 2020 and subtracted from the GPMM and MSR numbers, as the "floor" capacity is viewed as EIA's attempt to account for these other penetration pathways. This final result was then "hard-wired" into NEMS by OnLocation. This analysis does not reflect the additional demand consumers may have for solar energy because it provides increased reliability of service, an emergency source of power, and/or an improvement in load management capabilities. As a result, the benefits reported here understate the likely demand for solar energy.

- Least Cost Power - This segment is unlikely to provide much market opportunity for PV due to the high COEs projected for the foreseeable future. To develop this estimate, NEMS was run using a composite cost and performance trajectory, reflecting the lowest COE in a given period, taken from the *Renewable Energy Technology Characterizations.* The maximum share for intermittent generation and the short-term cost multipliers that indicate how quickly the industry can increase without cost penalties are modified based on analysis undertaken by the National Renewable Energy Laboratory, Lawrence Berkeley National Laboratory, and Princeton the Energy Resources International.

- Million Solar Roofs Initiative - The Million Solar Roofs initiative, which is scheduled to end in FY 2003, targeted the application of this technology to compete with retail electricity prices, not the very low competitive grid prices. The realization of MSR goals for PV, 600,000 systems installed by 2010, form the basis for the power penetration projected for MSR that are added to the GPMM projections to calculate FY 2004 benefits. Table 2 contains the MSR projections. Projections beyond 2010 assume declining annual growth rates, as would be expected to occur after the end of a major initiative.

Table 2. Million Solar Roofs Program Capacity Projections

	Annual Growth Rate (% above prior year)	Incremental Annual Capacity (MW)	Cumulative Capacity above 2003 baseline (MW)
2000	20%	25	-
2001	21%	30	-
2002	22%	37	-
2003	23%	45	-
2004	24%	56	56
2005	25%	70	127
2007	26%	89	215
2007	27%	113	328
2008	28%	144	472
2009	29%	186	658
2010	30%	242	900
2011	20%	290	1,190
2012	15%	334	1,523
2013	10%	367	1,890
2014	5%	385	2,275
2015	0%	385	2,660
2016	0%	385	3,046
2017	0%	385	3,431
2018	0%	385	3,816
2019	0%	385	4,201
2020	0%	385	4,586

Benefits

- Primary Energy Displaced — Photovoltaics displace conventional electricity on a kWh for kWh basis. The lower capacity factor of photovoltaics does mean, however, that the energy production of a GW of PV is not equivalent to the output of the same capacity of conventional coal capacity. In calculating energy displacement an average grid heat rate is assumed according to the *GPRA Data Call: Fiscal Year 2004*, declining over time by about 25% from 10,713 Btu/kWh.

- Energy Cost Savings — Energy cost savings are derived from energy displacement and average costs of producing electricity according to the *GPRA Data Call: Fiscal Year 2004* were used.

- Carbon Displacement — PV systems displace the carbon that would have been emitted by conventional power plants in producing the electricity. Average grid carbon emission factors according to the *GPRA Data Call: Fiscal Year 2004* are used and declining grid heat rates work again to lower the carbon emissions factor.

FY2004 GPRA METRICS
BIOMASS POWER

Table 1. Summary of Biopower Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Least Cost	0.00	0.00	0.02	0.11	0.26	0.41
Green	0.05	0.19	0.35	0.44	0.47	0.49
Other Biopower Initiatives	0.00	0.00	0.00	0.00	0.00	0.00
Total (may not add due to rounding)	0.05	0.19	0.37	0.55	0.73	0.90
Annual Benefits						
Fossil Fuel Energy Displaced[1] (TBtu)	3.55	12.2	21.5	30.3	40.2	50.0
Energy Cost Savings (millions of 2000 $)	-1.65	-13.9	-18.1	-14.8	-8.05	5.15
Carbon Displaced (MMCTE)	0.07	0.25	0.43	0.60	0.80	0.95
1) Biopower benefits are cited in terms of Fossil Fuel Energy Displaced because biomass has energy content associated with it.						
Technology Indicators[2]						
Cost ($/kW)	1,600	1,420	1,315	1,215		
Capacity Factor (%)	80	80	80	80		
Levelized Cost of Energy (cents/kWh in constant 1997$)	6.7	6.4	6.0	5.5		
2) Based on weighting of Gasification and Direct-fired technologies. *Renewable Energy Technology Characterization* data used for NEMS analysis. Levelized COE includes feedstock cost of $2.50/GJ at a heat rate of 9730 kJ/kWh in 2005 and 2010 and of 8760 kJ/kWh in 2015 and 2020.						

Market Segments

Biopower systems are expected to penetrate in two market segments: the green power market and the least cost power market. This expectation is due largely to biopower's competitive cost of energy.

- Green Power - In the GPMM, gasification and direct-fired technologies were considered. Gasification is an emerging technology that is expected to penetrate modestly in the Green Power market segment. Direct-fired biopower is a well-established technology expected to be used primarily in cogeneration applications at industrial locations, which are modeled under the DEER program analysis, but also expects some penetration through the green power market. Because biomass-generated electricity is so competitive economically and the resource widely available, it is projected to be installed as a green power option in every region of the country. Due to the revisions in the assumptions of sectoral energy consumption and prices, the estimates of green power capacity additions have been lowered for all technologies, when compared to last year's results. The cost and performance data in the *Renewable Energy Technology Characterizations* were used for both technologies. Projections for total green market potential are taken from NREL, *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy* (NREL/TP-620-30101).

- Least Cost Power - Gasification is the only technology modeled in NEMS, representing the most likely technology configuration to be installed in future utility-scale biopower systems. Project contingency factors in NEMS have been set to zero (from their default value of 7%).

Benefits are calculated assuming that the gasification technology replaces a natural gas-fired turbine and the direct-fired technology displaces a coal boiler. Industrial biomass cogeneration applications are accounted for under the DEER program, and the biopower program is not given any credit for this capacity. The results of the analyses and key technology indicators are shown in Table 1. The results of the GPRA 2004 analysis have decreased in comparison to the GPRA 2003 reported figures.

FY2004 GPRA METRICS
WIND

Table 1. Summary of Wind Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Least Cost	0.80	2.05	14.8	29.2	43.8	58.3
Green	0.70	2.60	4.35	4.60	4.70	4.95
Distributed	Included in green power					
Total (may not add due to rounding)	1.50	4.65	19.2	33.8	48.5	63.0
Annual Benefits						
Energy Displaced (TBtu)	59.0	157	655	1,115	1,610	2,105
Energy Cost Savings (millions of 2000 $)	146	359	1,725	3,180	4,840	6,695
Carbon Displaced (MMCTE)	1.10	3.20	13.0	21.7	31.3	40.9
Technology Indicators[1]						
Cost ($/kW)	900	835	825	805		
Capacity Factor (%)	42.0	48.1	48.7	50.5		
Levelized Cost of Energy (cents/kWh in constant 1997$)	3.0	2.6	2.6	2.5		

1) *Technology Indicators* data represents a weighted average of new wind turbine characteristics for Class 4 (5.8 m/s average wind speeds) and Class 6 (6.7 m/s) sites, as defined by program planning documents for the Low Wind Speed Turbine project. Weighting changes from 20/80 for class 4/class 6 in 2004 to 75/25 in 2030.

Note: The capacity, generation and benefits reported in the FY2004 Budget Submission documentation for this program include both wind and hydropower estimates. However, the results presented in this report include only the amount of capacity projected to be installed for wind technologies. Hydropower capacity and generation additions have been excluded from this report, and as such, the values shown here differ from those reported in the FY2004 Budget Submission documentation.

Note: The program's hydropower technology goal of reducing fish mortality associated with hydropower production is largely intended to improve the potential for relicensing of existing facilities, so that this existing capacity is not lost. As such, this goal is effectively incorporated into the NEMS-GPRA04 program case as relicensed capacity: the AEO 2002 Reference Case assumes relatively constant hydroelectric capacity, which requires essentially all existing hydro-

electric facilities to be successfully relicensed. Based on analysis undertaken for the Idaho National Engineering Laboratory, the Baseline is revised to remove 1.0 GW and 5 BkWh of hydroelectric power by 2007, increasing to 1.5 GW and 7 BkWh by 2020 to reflect the levels of expected loss of capacity due to concerns related to fish-kill. This hydropower is then re-introduced in the program case.

Market Segments

Wind technologies are expected to be installed in two market segments:

- Green Power - Wind is one of the main competitors in the green power market segment. This market segment and the model used to analyze it are described in Appendix C. Wind, as one of the lowest-cost renewable technologies, competes successfully with the other technologies and thus captures about 63% (40% when MSR and floor capacity is included) of the green market in 2020. There are already several examples of wind energy being installed to meet the demands for green power. The GPMM is regional and wind penetrated every region extensively, except for the South Atlantic and East South Central regions, where wind is excluded from the model due to low resource potential.

- Least Cost Power - This segment has traditionally been considered to have the largest potential for market penetration (as measured by rated capacity) for wind energy. This market segment continues to provide the largest portion of projected penetration, accounting for 86% of the projected capacity additions of wind power by 2020. Market penetration estimates were developed using NEMS, which competes wind against all other generators in this segment. The NEMS analyses were performed by OnLocation. Green power estimates were explicitly included in NEMS prior to the least cost runs because NEMS does not yet effectively predict penetration into that segment. The program goals for wind technologies are modeled directly in NEMS-GPRA04 by incorporating the capital costs, operations and maintenance (O&M) cost, and capacity factors consistent with the program's low wind speed technology goal of 3 cents per kWh by 2012 into the model. For both the Baseline and GPRA cases, the maximum share of electricity generation allowed from intermittent sources was raised from the 12 percent used by EIA to 30 percent, based on experience in other countries. Short-term cost multipliers that indicate how quickly the industry can increase production without driving up the production costs are modified as a result of consultation with NREL, LBNL, and PERI, based on worldwide experience. Thus, the expansion of wind energy without cost penalties associated with manufacturing constraints was increased from 50 percent of installed capacity to 100 percent to reflect the fact that the industry is global and has shown the capability to expand rapidly in the last several years. The benefits estimates are conservative because the wind resource curve in the NEMS model involves assumptions that significantly increase the capital cost of developing new wind resources in ways that are inconsistent with market conditions in nations that have already significantly expanded wind production. Finally, the Production Tax Credit is assumed to run through 2003.

FY2004 GPRA METRICS
GEOTHERMAL

Table 1. Summary of Geothermal Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Least Cost	0.00	1.60	3.80	6.05	8.45	10.8
Green	0.05	0.21	0.42	0.60	0.65	0.70
Enhanced Geothermal Systems	0.00	0.00	0.00	0.00	0.00	0.00
Total (may not add due to rounding)	0.05	1.80	4.20	6.65	9.10	11.6
Annual Benefits						
Energy Displaced (TBtu)	4.25	132	283	425	580	735
Energy Cost Savings (millions of 2000 $)	10.6	301	745	1,215	1,745	2,340
Carbon Displaced (MMCTE)	0.08	2.70	5.60	8.25	11.3	14.3
Technology Indicators*						
Cost ($/kW)	1,430	1,215	1,165	1,115		
Capacity Factor (%)	93.0	95.0	95.5	96.0		
Levelized Cost of Energy (cents/kWh in constant 1997$)	2.9	2.4	2.3	2.1		

*Weighted average of Flash and Binary Geothermal technologies, based on capacity projections. Data taken from *Renewable Energy Technology Characterization* report. These are provided for comparative purposes only, since the NEMS analysis of geothermal uses site-specific cost data.

Market Segments

Geothermal power is expected to penetrate in two market segments: the green power market and the least cost power market. No distributed uses of geothermal were projected, although there is emerging industry interest in such applications, and a new DOE program to explore small-scale modular geothermal plant technology development (<5 MW).

- Green Power - Flash, Binary, and Enhanced Geothermal Systems (EGS) technologies were all modeled as potential geothermal power plants that could be installed to meet the

emerging green power market. Flash and Binary technologies compete well within the green power market, with Flash technology out-gaining Binary due to its more attractive cost curve. EGS technologies have significant cost penalties that restrict capacity additions until after 2015, and even then only a very limited amount of EGS power is projected to be built to meet green power demand. Although geothermal plants were limited to the western portion of the United States, they were typically one of the least expensive options in those regions, leading to significant penetration in those two regions. Projections for total green market potential are taken from NREL, *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy* (NREL/TP-620-30101).

- Least Cost Power - NEMS was run to estimate market penetration into the competitive bulk power marketplace for Geothermal Flash technology. The program goals for geothermal technology improvements are modeled directly in NEMS-GPRA04 by incorporating the capital and operation and maintenance (O&M) cost reductions. The model also takes into account site availability and maximum development per site per year for conventional and Enhanced Geothermal Systems (EGS) geothermal capacity. The conventional geothermal characteristics modeled are from the EPRI/DOE *Renewable Energy Technology Characterizations* report, and the EGS characteristics are developed by Princeton Energy Resources International (PERI). The NEMS model represents individual geothermal sites with different characteristics, with the lowest cost sites being developed first. For the GPRA 2004 analysis, OnLocation has eliminated the construction delay between projects (both large and small) at individual sites. NEMS' limits on amounts of capacity that can be built in any single year at one location have been increased to 100 MW from the prior 50 MW limit. OnLocation has also implemented a code change that better represents the mix of high and low resource areas that are represented in NEMS.

FY2004 GPRA METRICS
DISTRIBUTED ENERGY AND ELECTRIC RELIABILITY PROGRAM

Table 1. Summary of Overall Distributed Program Analysis

	2005	2010	2015	2020	2025	2030
Market Penetration Estimate (Cumulative GW installed above Baseline)						
Total	2.30	7.45	16.3	25.0	33.8	42.6
Annual Benefits						
Energy Displaced (TBtu)	117	294	550	775	1,045	1,315
Energy Cost Savings (millions of 2000 $)	0.50	1.55	3.35	5.25	7.05	8.80
Carbon Displaced (MMCTE)	2.60	7.70	14.4	20.1	27.1	34.1

Market Segments

The Distributed Energy and Electric Reliability (DEER) Program sponsors a wide range of research activities, including advanced turbines and microturbines, natural gas engines, PEM fuel cells, thermally activated technologies, and combined heat and power (CHP) among others. Many of the programs formerly reported separately under Electricity Delivery Programs, such as High Temperature Superconductivity (HTS), Renewable Energy Production Incentive (REPI), Transmission reliability, Energy Storage, Distribution and Interconnection, and Distributed Generation, have been incorporated into the new DEER program. As such, the benefits of these programs are reported under the DEER program. DEER benefits are calculated from the CHP capacity and generation additions modeled in NEMS. Additionally, the Hydrogen program does not receive any credit for hydrogen fuel cell penetration expected in the CHP market. This capacity is credited to the DEER program.

Because of the diversity of the program's efforts and the broad array of market opportunities that present themselves to the various DEER technologies, EERE has used a simplified approach to calculating the benefits of the DEER program. That approach is based on the fact that the overwhelmingly largest benefit will come from the installation of combined heat and power (CHP) systems. Therefore, an analysis of the potential of CHP systems in the U.S. market place was undertaken for GPRA 2004. The results of that analysis were used as a surrogate for the total program benefits.

For the GPRA 2004 benefits analysis, EERE used NEMS commercial and industrial sector CHP analysis modules. The NEMS-GPRA04 baseline limits the rate of new technology adoption and the maximum share of DG technologies based on the extent to which future markets are expected to be able to accommodate these technologies. The program goals for development of distributed electricity technologies (microturbines, reciprocating gas engines, and IC engines at 800 kW and 3,000 kW) are modeled directly in NEMS-GPRA04 by incorporating the improved costs,

efficiencies, and other attributes in NEMS-GPRA04 for the program case. The portions of the program designed to enhance the ability of electricity markets to absorb and manage DG are modeled by increasing the maximum CHP market share. Because NEMS-GPRA04 cannot model markets for high-temperature superconductivity (HTS) products, the benefits from these products are modeled directly as reductions in transmission and distribution losses for electricity systems, based on estimates by Energetics of kilowatt-hour reductions from HTS generators, transformers, cables, and motors. The portions of the program that reduce market barriers to consumer investment are addressed by adjusting the model's consumer acceptance curves (market adoption rates by payback period) for CHP.

Not all kWh of electricity have equal value to consumers. Market experience suggests that at least a portion of consumers are willing to pay more for electricity that is more reliable, of higher quality, locally controllable, available during emergency, or cleaner. While market information was available to incorporate the impact of "green power" preferences in these benefit estimates, they do not include consumer purchases based on preferences for improved reliability, load management, or power quality advantages of distributed generation. As a result, these benefit estimates are likely based on an underestimate of the demand for these products under baseline market assumptions.

Results

The results of the NEMS CHP analysis are shown in Table 2 for capacity and Table 3 for generation. NEMS projects that 7.45 GW of additional capacity, above revised AEO 2002 baseline, will be installed by 2010. The bulk of those installations, 7.21 GW, are projected to be in the industrial sector. The NEMS analysis for CHP is based on payback calculated from average prices, and is documented by the Energy Information Administration.

A determination of the fuel-use of these technologies was required to calculate the benefits from CHP introduction. Industrial applications are split between natural gas, coal, oil and biomass. Natural gas is by far the most dominant fuel choice, accounting for 69%-81% of total CHP capacity projections in the NEMS-GPRA04 and AEO02 baseline runs, and 100% of the projected benefits (i.e., the difference between these runs). Industrial biomass cogeneration represents about 10% of total CHP capacity, however no additional biomass is projected by the NEMS-GPRA04 run above the revised AEO02 baseline, and therefore biomass cogeneration receives no benefits for capacity additions. The analysis assumes 100% natural gas use for commercial applications.

Table 2. Cumulative CHP Capacity Additions above AEO 2002 baseline for GPRA 2004

Cumulative Capacity Additions (GW)	2005	2010	2015	2020	2025	2030
Industrial- Biopower	0.0	0.0	0.0	0.0	0.0	0.0
Industrial- Natural Gas	2.21	7.21	15.7	23.9	32.1	40.3
Industrial- Coal	0.00	0.00	0.00	0.00	0.00	0.00
Industrial- Oil	0.00	0.00	0.00	0.00	0.00	0.00
Industrial- Total	2.21	7.21	15.7	23.9	32.1	40.3
Commercial- Total	0.10	0.24	0.54	1.14	1.68	2.24
DEER- Total	2.30	7.45	16.3	25.0	33.8	42.6

Table 3. Generation from CHP Capacity Additions above AEO 2002 baseline for GPRA 2004

Cumulative Capacity Additions (GW)	2005	2010	2015	2020	2025	2030
Industrial- Biopower	0.0	0.0	0.0	0.0	0.0	0.0
Industrial- Natural Gas	16.0	52.0	113	172	231	290
Industrial- Coal	0.0	0.0	0.0	0.0	0.0	0.0
Industrial- Oil	0.0	0.0	0.0	0.0	0.0	0.0
Industrial- Total	16.0	52.0	113	172	231	290
Commercial- Total	0.69	1.75	3.87	8.23	12.1	16.1
DEER- Total	16.7	53.8	117	180	243	307

Benefits from the generation displaced from the grid are then calculated using the following procedures. Both industrial and commercial energy balance calculations are performed, as these sectors have different energy efficiencies and prices. The energy consumed on-site with CHP is netted out against the energy that was used on-site prior to the implementation of CHP and the energy supplied in the form of electricity by the grid. The energy content of the displaced electricity is calculated using both electricity generation and end-use consumption heat rates. The latter is used to calculate the net primary energy displacement and cost savings, as this is the amount of energy that is displaced at the site. However, since the emissions displaced are produced not on site, but rather at the point of generation, the energy content of the electricity at generation must be calculated as well to realize the true net emissions savings. Emissions from CHP systems using natural gas are generally low. Benefits of energy cost savings, carbon emissions savings, and are then calculated in accordance with the GPRA FY2004 guidance document.

Appendix A. Market Segmentation

The market segmentation used in the analysis is shown in Figure A1. At the highest level, the market was divided into: 1) Grid-Side Systems -- systems that are on the grid side of the meter, and owned by utilities or other power suppliers; and 2) Customer-Side Systems -- systems installed at customer locations on the customer side of the meter.

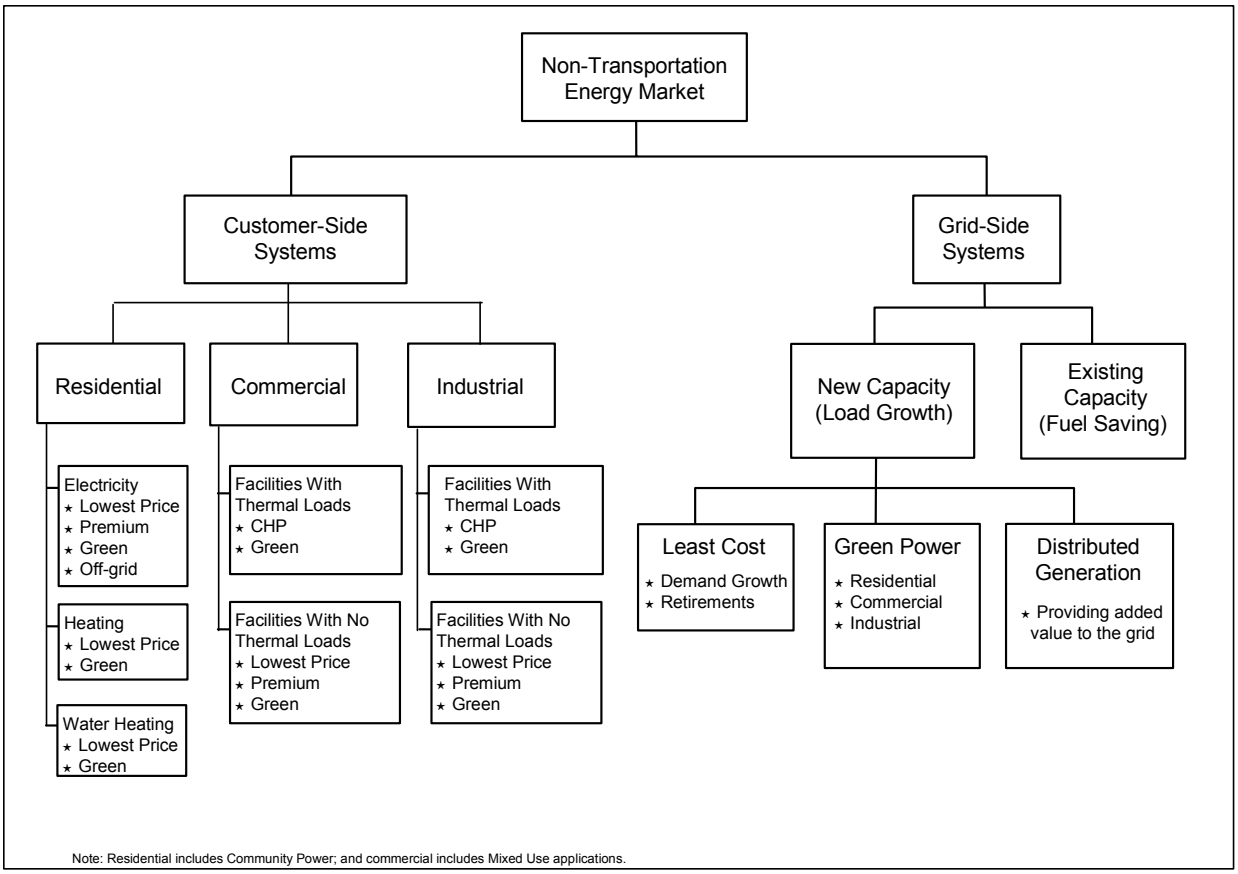

Figure A1. Market Segmentation of EERE Programs.

<u>Grid-Side Systems Segment</u>

The grid-side power segment includes power plants installed at either the transmission system level or at the distribution system level. This segment has traditionally been the realm of the regulated utility and, since 1978, the qualifying facility (QF). For modeling purposes, Grid-Side Power was subdivided into two sub-elements -- new capacity and existing capacity. The former considers capacity additions required to meet demand growth and those required to satisfy capacity needs created by plant retirements. The existing capacity subsegment consider those instances when the costs of generation from either biomass co-firing or intermittent wind and solar plants are less than the variable costs of operating existing plant capacity. This is commonly termed the fuel-saving market.

New capacity requirements have traditionally been met by new plants installed as a result of utility planning processes. As electricity markets are restructured, new business arrangements for satisfying this demand will emerge, but this segment will continue to represent the bulk of the capacity and generation supplied to the grid. (In the evolving restructured market, "merchant" power plants will also be constructed that compete with less-efficient, more-costly existing capacity. The analysis assumed that merchant renewable plants will be few in number.) This least cost subsegment could, in principle, be satisfied by capacity installed at either transmission system level voltages or at distributed system voltages. The former will typically be larger systems (central station) and the latter will be smaller systems (dispersed throughout the distribution system). The analysis characterized the costs and performance of both large and small plant sizes and allowed them to compete as appropriate for new capacity requirements. It must be emphasized that in this subsegment the distribution-level systems are installed solely for their capacity and generation value. No additional benefits to the utility system are considered. Plants that offer such "distributed benefits" are explicitly included in the Distributed Generation subsegment (see discussion later).

Green Power is a term that describes the public's apparent interest in renewable generation as a responsible alternative to conventional energy supply. Customers can acquire *Green Power* either by purchasing it from a supplier, or by installing their own system. The market segmentation reflects both of these options. (Note -- the customer-side green subsegment, shown in Figure A1, was explored for photovoltaics.) The *Green Power* subsegment of the Grid-Side Power segment is an evolving market that the analysis examined explicitly. It included two closely related marketing mechanisms for offering end-users the opportunity to purchase power that is generated by environmentally responsible means. *Green Pricing* is a mechanism by which regulated electric utilities have an approved tariff under which their customers can chose to pay additional monies to ensure that green electricity will be provided by their utility. However, more generally under a deregulated utility supply system, *Green Marketing* programs will include a variety of opportunities through which customers pay a premium to ensure that they are "buying" electricity from green sources.

The *Distributed Generation* subsegment of the Grid-Side Systems segment is also a specialized market. The Distributed Generation portion of the analysis accounted for those site-specific instances where small-scale generating systems or storage systems provide cost-saving benefits to the grid that go beyond pure capacity and generation values. These system benefits are often described as being valuable in supporting weak elements of the distribution system, or as helping alleviate pressures on the distribution system due to rapid load growth on parts of the system. Because this subsegment is just now developing, no installations which are directly attributable to distribution systems were projected.

Customer-Side Systems Segment

The Customer-Side Systems segment was analyzed in three sub-segments: residential, commercial, and industrial, including cogeneration.

Elements of the residential segment include: 1) systems that are owned because they are less-expensive than purchased alternatives (the lowest price element); 2) systems that offer added

value to the owner beyond the basic commodity value of electricity, e.g., a desire to have reliable power independent of grid supply -- this value-added element could also have a green component (the value-added element); 3) systems that are green and are purchased for that reason, despite the fact that they are more expensive (the green element); and 4) systems that meet off-grid needs where conventional supplies are either unavailable or prohibitively expensive (the off-grid element).

The commercial and industrial subsegments mirror the residential, although there may be fewer opportunities for the off-grid market element. Cogeneration is defined as a separate element in the industrial subsegment because it is analyzed as a distinct market and was modeled in the National Energy Modeling System (NEMS) Industrial Demand Module and credited to the DEER program.

Appendix B. Overview of Modeling Framework

Table B1 shows the suite of models and analytical tools that EERE used for the analysis. The four Renewable Energy Technology Programs were analyzed using NEMS and the Green Power Market Model. The Solar Buildings program used an exogenous model, prepared by Princeton Energy Resources International. Customer-side Photovoltaics penetration, under the Million Solar Roofs program, was estimated using an exogenous model. The DEER program was modeled in NEMS alone, using the CHP capacity and generation additions as the basis for DEER benefits.

Table B1. Overview of EERE Analysis Approach

EERE Program Element	**NEMS**	**Green Power Market Model**	**Exogenous Models**
Solar Buildings			
Photovoltaics			
Biomass			
Wind			
Geothermal			
Distributed Energy and Electric Reliability			

Appendix C. Green Power Market Model

Introduction

The Green Power Market Model (GPMM or the model) identifies and analyzes the potential generating capacity additions for electricity production that will result from "green power" (either green marketing or pricing) programs, which are not captured in the "least-cost" analyses performed by the National Energy Modeling System (NEMS). Princeton Energy Resources International, LLC (PERI) originally constructed the GPMM in August and September 2000, as a sub-module, with the results hard wired into NEMS as planned capacity. This year's model, based in Microsoft Excel 97, is consistent with efforts from last year, with several changes documented herein. Several significant changes were incorporated last year that were not changed for this year's analysis, including a more detailed and regionalized set of assumptions for electricity market restructuring. These assumptions come from the *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy*, a recent report by Blair Swezey et al. completed for the National Renewable Energy Laboratory (NREL). The assumptions include the dates for initiation of market restructuring as well as the assumed green power penetration rates, a change in the time periods tracked in the analysis, and a new method for calculating funds from program participants.

Green technologies are marketed as energy production in a cleaner, safer, and renewable fashion. However, the definitions of what constitutes a green technology and how it should be marketed are quite ambiguous in the early deregulation arena. Several agencies and organizations have identified this ambiguity and have offered suggestions. The American Wind Energy Association's (AWEA) *Principles of Green Marketing* was developed in an "effort to foster a credible market in environmentally-preferable electric services… that results in meaningful changes in the electric system as whole." Lawrence Berkeley National Laboratory's (LBNL) *Green Power Certification* report points out the need for creation of certification programs to validate retailers' claims of providing green energy. Several organizations have begun to certify green power marketing claims and sales agreements in areas with competitive access to power available, including the Center for Resource Solutions' (CRS) Green-e program, the Scientific Certification Services' (SCS) Environmentally Preferable Power program, and the Environmental Resource Trust's EcoPower program.

The Green Power Network, a part of the US Department of Energy (DOE), defines both green power and green power marketing on their web page. It states that the "essence of green power marketing is to provide market-based choices for electricity consumers to purchase power from environmentally preferred sources. The term "green power" is used to define power generated from renewable energy sources, such as wind and solar power, geothermal, hydropower and various forms of biomass."

For purposes of this analysis, the term "green marketing" refers to selling green power in the competitive marketplace, in which multiple suppliers and service offerings exist. Green marketing programs occur in restructured markets that were formerly served by either investor-owned utilities (IOU) or public utility companies (PUC) and give the customer the option of paying a market price (higher if necessary) to ensure that their electricity demand is met by green power. "Green pricing" programs, on the other hand, represent the programs sponsored by

utilities that give customers the opportunity to pay extra to support the development and operation of green power sources. Those utilities, both IOUs and PUCs, which remain regulated in our analysis have the option of providing "green pricing" programs.

The Model

Technologies:

The model projects additional capacity and electricity generated from green technologies for the periods 2004 to 2008 and 2009 to 2010, and then five-year periods to 2030. Sixteen individual technologies, comprising five technology types, were selected as both green and commercially viable for this analysis. The technologies, listed below, can be grouped into categories based on both the availability of power, Dispatchable or Intermittent, and on resource use. These are:

Dispatchable:

1) Biomass:	- Direct-Fired Biomass - Biomass Gasification - Landfill Gas
2) Geothermal:	- Flash Geothermal - Binary Geothermal - Hot Dry Rock
3a) Concentrated Solar Power:	- Solar Thermal Trough - Solar Thermal Dish- Hybrid - Solar Central Receiver

Intermittent:

3b) Concentrated Solar Power	- Solar Central Receiver (Intermittent) - Solar Thermal Dish- Stand Alone
4) Photovoltaics:	- Residential PV (Neighborhood) - Central Station PV (Thin Film) - Concentrator PV
5) Wind:	- Wind Turbines

Although the model was initially designed to distinguish between dispatchable and intermittent technologies, more recent versions of the model exclude this distinction. The original distinction was accomplished by adding an extra cost to intermittent technologies associated with "firming up" the technologies' ability to provide a constant power supply. Generally, the additional capacity needed to maintain stability of power comes in the form of diesel generators or gas turbines, for which the model calculated these additional costs. However, since green power programs only guarantee that a certain percentage of total kilowatt-hours generated will come from green sources over the course of a year, the developers of new green power do not have the incentive to include back-up generation to provide a continuous source of power. Developers are assumed to build the sites in least cost fashion (without back-up) and take the "green" electrons when and from where they are able. The "firm up" costs are now set to zero in the model, which effectively removes the competitive advantage, and therefore the distinction, of dispatchable sources over intermittents.

Regions:
The model is composed of regional segments, used to capture differences in the costs of competing technologies, resource availability, levels of participation in voluntary green marketing programs, and electricity demand by sector. PERI has elected to use US Census regions as the breakdown, as the availability of regional data for the model often takes this format. Eight regions (South Atlantic and East South Central have been combined) are modeled independently, and then summed to produce national results. The regions for this analysis are 1) New England, 2) Middle Atlantic, 3) East North Central, 4) West North Central, 5) South Atlantic and East South Central, 6) West South Central, 7) Mountain, and 8) Pacific.

This regional breakdown is different from the regional divisions of NEMS, however. In order to be hardwired into NEMS, the eight regional capacity projections must be converted to thirteen divisions used in NEMS. The NEMS divisions are based on the North American Electric Reliability Council's regions. The names of these regions, and the conversion formulas from the census region breakdown are documented in the model.

The state-by-state restructuring and penetration assumptions taken from the *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy* (the NREL report) are summed across these regions, and are pro-rated based on the loads of the electric market in each state compared to the region as a whole.

Revisions to the FY04 Model:
Several revisions to the FY03 GPMM have been made in the update for FY04. The reporting of years has been changed from 2003-7 and 2008-10 to 2004-8 and 2009-10, with the five-year increments thereafter to 2030 remaining consistent. New technology characterizations for wind, class 4 and 6 data averaged, and CSP, trough and power tower data, were taken from program revisions to the *Renewable Energy Technology Characterizations, EPRI-TR109496* report (TC report). All other technologies remained consistent in using the TC report. All technology cost figures were converted to 2000$, using GPD price deflators from http://w3.access.gpo.gov/usbudget/fy2001/sheets/hist10z1.xls.

Most of the major assumptions of the GPMM remained unchanged. The model still incorporates extensive revisions to the assumptions included for the FY03 model. Many of these assumptions, including the rates at which electricity markets restructure, and the participation levels of customers in these new markets were taken from *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy, NREL/TP-620-30101* (the NREL report).

The regional economic sectors' energy consumption and prices were updated according to the new Energy Information Administration's (EIA) assumptions for the *Annual Energy Outlook 2002, DOE/EIA-0383(2002)* (AEO2002). The regional energy consumption and prices were taken from tables 1-20 of AEO2002 Supplemental Data Tables. Tables 1-3, on the following pages, show the differences in regional energy consumption and prices for the residential, commercial and industrial sectors between the FY03 and the FY04 models.

Table 1. Residential Energy Consumption and Prices by Census Region.

Census Region	Model Year	1999/2000 Residential Energy Consumption (Quads)	2020 Residential Energy Consumption (Quads)	1999/2000 Residential Energy Prices (2000$/MMBtu)	2020 Residential Energy Prices (2000$/MMBtu)
National	FY03	3.91	5.80	23.95	22.50
	FY04	4.07	5.70	24.36	22.55
New England	FY03	0.14	0.20	33.26	29.84
	FY04	0.14	0.19	34.04	30.97
Mid. Atlantic	FY03	0.38	0.50	31.74	28.34
	FY04	0.38	0.49	32.22	29.03
E. N. Central	FY03	0.56	0.82	23.33	20.61
	FY04	0.58	0.83	23.24	20.99
W.N. Central	FY03	0.29	0.40	20.87	20.32
	FY04	0.30	0.41	22.04	20.16
S. Atlantic & E.S. Central	FY03	1.27	1.95	22.00	21.88
	FY04	1.35	1.95	23.29	21.09
W.S. Central	FY03	0.57	0.90	21.10	20.89
	FY04	0.61	0.87	21.87	20.90
Mountain	FY03	0.23	0.38	22.38	22.41
	FY04	0.25	0.39	21.73	22.69
Pacific	FY03	0.46	0.66	25.37	23.65
	FY04	0.46	0.59	25.64	25.49

Table 2. Commercial Energy Consumption and Prices by Census Region.

Census Region	Model Year	1999/2000 Commercial Energy Consumption (Quads)	2020 Commercial Energy Consumption (Quads)	1999/2000 Commercial Energy Prices (2000$/MMBtu)	2020 Commercial Energy Prices (2000$/MMBtu)
National	FY03	3.70	5.61	21.86	18.39
	FY04	3.91	6.12	22.11	20.33
New England	FY03	0.16	0.22	28.23	19.99
	FY04	0.14	0.19	28.55	23.81
Mid. Atlantic	FY03	0.47	0.63	16.78	14.02
	FY04	0.49	0.63	28.25	24.73
E. N. Central	FY03	0.56	0.82	21.15	17.64
	FY04	0.55	0.74	20.68	19.50
W.N. Central	FY03	0.25	0.37	19.24	17.67
	FY04	0.28	0.41	18.11	17.16
S. Atlantic & E.S. Central	FY03	1.06	1.67	19.24	18.00
	FY04	1.11	1.95	20.15	19.07
W.S. Central	FY03	0.46	0.70	18.91	17.72
	FY04	0.49	0.72	19.07	18.52
Mountain	FY03	0.25	0.42	18.54	18.12
	FY04	0.28	0.52	18.77	19.32
Pacific	FY03	0.49	0.79	24.90	18.68
	FY04	0.56	0.95	26.64	23.01

Table 3. Industrial Energy Consumption and Prices by Census Region.

Census Region	Model Year	1999/2000 Industrial Energy Consumption (Quads)	2020 Industrial Energy Consumption (Quads)	1999/2000 Industrial Energy Prices (2000$/MMBtu)	2020 Industrial Energy Prices (2000$/MMBtu)
National	FY03	3.63	4.81	13.29	11.79
	FY04	3.65	4.83	13.50	13.04
New England	FY03	0.09	0.11	22.40	15.15
	FY04	0.09	0.11	22.64	18.15
Mid. Atlantic	FY03	0.30	0.37	20.65	16.34
	FY04	0.29	0.36	17.05	16.88
E. N. Central	FY03	0.77	0.99	12.77	11.71
	FY04	0.78	1.00	13.13	13.44
W.N. Central	FY03	0.27	0.35	12.35	11.11
	FY04	0.29	0.36	12.36	11.36
S. Atlantic & E.S. Central	FY03	0.98	1.30	12.57	11.76
	FY04	1.00	1.31	12.82	12.45
W.S. Central	FY03	0.56	0.76	11.50	11.98
	FY04	0.56	0.77	11.70	12.58
Mountain	FY03	0.24	0.34	12.10	11.29
	FY04	0.24	0.33	11.47	11.69
Pacific	FY03	0.41	0.59	15.11	10.54
	FY04	0.41	0.59	15.70	13.17

As can be seen from Tables 1-3, some notable differences occur in the economic sector demand assumptions in energy consumption and prices. In the residential sector, Table 1, the residential energy consumption for the nation increased 2% in the beginning (1999-2000), from 3.91 to 4.07 Quads, but decreased 4% at the end (2020), from 5.80 to 5.70 Quads, of the analysis period. This reduced the growth rate of energy consumption for the country as a whole, which in turn reduces the average monthly electric bills, the pool of green money, and the total capacity built to meet green power market demand. The national residential energy prices (in 2000$) increased only slightly, 2%, for the beginning of the analysis and did not effectively change for the end of the period. On a regional level for the residential sector, the largest differences were seen in the Pacific region, where energy consumption in 2020 decreased by 11% while prices rose 8% in 2020.

Table 2 shows the commercial sector demand assumptions. The most noted change is increases of 68% and 76%, respectively, of the Middle Atlantic region's commercial energy prices in 1999-2000 and 2020. Other significant changes include a reduction in commercial energy consumption in the New England and East North Central regions, while consumption levels increased in the Mountain and Pacific regions.

Table 3 shows the industrial sector demand assumptions, which remained the most consistent from FY03 to FY04. The current energy prices (1999-2000) for the Middle Atlantic region dropped 17%. On the other hand, future energy prices (2020) increased by 25% and 20%, respectively, for the Pacific and New England regions.

The regional residential household data is used to calculate the size of the potential green power market for the residential sector. This data was updated for the FY04 model from a file sent by John Cymbalski, of the EIA. ("Regional hhs- updated from J Cymbalski 6-5-02.xls") The regional household data generally increased or decreased by only 1% to 2%, with the exception of the Pacific and West South Central regions, which had the largest deviation, increases of 5.3% and 4.9%, respectively, in 2020. Increasing households in a region has the effect of generating a larger potential green electric market and therefore more green revenues, which would increase GPMM capacity builds in that region.

The commercial floorspace and industrial gross output are used to determine the number of commercial and industrial establishments, respectively. Similar to the number of households, the number of establishments, combined with electric market restructuring and participation levels from the NREL report, determines the size of the potential green power markets for the commercial and industrial sectors, and therefore the GPMM capacity builds in each region. National data for commercial floorspace and industrial gross output was taken from Tables 22 and 23 of AEO2002 Supplemental Data Tables. These tables do not provide regional data of commercial floorspace or industrial gross output. Therefore, regional data was calculated on the basis of the national data and the regional percentages of the national total for these inputs in the FY03 model.

In addition to the economic sector demand data assumptions changed, a few other minor changes were made to the model. The regional limit on the amount of landfill gas (LFG) was modified so

that only 2/5 of the five-year regional limit of 70 MW was allowed for the two-year period from 2009 to 2010.

PERI included both additions and subtractions to the green capacity values for the Million Solar Roofs (MSR) capacity additions, and EIA "floors" builds, Tables 4-6. The MSR capacity additions, Table 4, are added to the green model numbers in the reporting of the PV-residential green capacity.

Table 4. Million Solar Roofs Initiative Incremental Capacity Additions in GPMM04

Year Period	MSR Capacity Additions (above 2003 Baseline)
2004-2008	472
2009-2010	428
2011-2015	1,761
2016-2020	1,926
2021-2025	1,926
2026-2030	1,926
Total for 2004-2030	8,439

An additional 250 MW of central station PV and 54.5 MW of central station solar thermal "floors" capacity from 2001 to 2020 are "assumed by EIA to be installed for reasons in addition to least-cost electricity supply". These "floors" capacity additions, Table 5, are prorated for 2004 to 2020 and regionally divided.

Table 5. EIA "Floors" Incremental Capacity Additions for PV and Solar Thermal in NEMS

Year Period	EIA PV "Floors" Capacity Additions (above 2003 Baseline)	EIA Solar Thermal "Floors" Capacity Additions (above 2003 Baseline)
2004-2008	62.5	13.6
2009-2010	25.0	5.5
2011-2015	62.5	13.6
2016-2020	62.5	13.6
2021-2025	0.0	0.0
2026-2030	0.0	0.0
Total for 2004-2030	212.5	46.3

These amounts are then subtracted from the green power builds for each region. However, if the prorated regional portion of the "floors" additions was greater than the regional builds in the GPMM, only the amount predicted to be built by the GPMM was subtracted (i.e. value reported as zero, no negative numbers reported), Table 6. As can be seen in Table 6, all of the Solar Thermal "floors" additions were subtracted from the GPMM04 results. At the same time, only a portion of the PV "floors" additions in the first two time periods were subtracted due to less capacity being built in each of the regions by the GPMM04 then was added by the "floors" capacity.

Table 6. EIA "Floors" Incremental Capacity Additions Subtracted from the GPMM04

Year Period	EIA PV "Floors" Capacity Additions Subtracted from GPMM04 (above 2003 Baseline)	EIA Solar Thermal "Floors" Capacity Additions Subtracted from GPMM04 (above 2003 Baseline)
2004-2008	17.8	13.6
2009-2010	22.6	5.5
2011-2015	62.5	13.6
2016-2020	62.0	13.6
2021-2025	0.0	0.0
2026-2030	0.0	0.0
Total for 2004-2030	164.9	46.3

Results

Comparison of Final Results:

Table 7 and 8 show the final results of the GPMM03 and GPMM04 that were hardwired into the NEMS AL01 and AL02 runs, respectively. However, due to the changes that are detailed in this report, including MSR additions and subtracting out EIA "floors" additions, these tables are not directly comparable. Table 9 shows the results of the GPMM04 without including MSR additions and subtracting out EIA "floors" additions.

Table 10 is then calculated as the difference between Table 7 and Table 9, and shows the changes in the results of the GPMM due to changes in the assumptions, rather than due to changes in the methodologies. As can be seen in Table 10, the total additions are relatively stable, with most of the changes seen between technologies. Wind and CSP see large increases while the other technologies all lose capacity gains. This is due to the revised technology characterization data for wind and solar thermal, lowering the capital costs and cost of energy, and therefore making these choices more attractive in the model.

Table 7. Results of the GPMM03- Cumulative Capacity Additions Relative to 2002 Baseline

	2010	**2020**	**2030**
Biomass (incl. LFG)	388	823	972
Geothermal	261	694	820
CSP	209	609	703
PV	143	668	963
Wind	2,418	4,462	4,842
Total	3,419	7,256	8,299

Table 8. Results of the GPMM04- Cumulative Capacity Additions Relative to 2003 Baseline

	2010	**2020**	**2030**
Biomass (incl. LFG)	287	673	802
Geothermal	209	600	705
CSP*	257	801	970
PV*	968	4,973	9,045
Wind	2,632	4,601	4,948
Total	4,353	11,648	16,470

Table 9. Results of the GPMM04- Cumulative Capacity Additions Relative to 2003 Baseline Without Methodology Changes from the GPMM03.

	2010	**2020**	**2030**
Biomass (incl. LFG)	287	673	802
Geothermal	209	600	705
CSP*	276	847	1,017
PV*	108	551	771
Wind	2,632	4,601	4,948
Total	3,512	7,272	8,242

Table 10. Difference in the Results of the GPMM04 Compared to the GPMM03 Without Methodology Changes from the GPMM03.

	2010	**2020**	**2030**
Biomass (incl. LFG)	-101	-149	-170
Geothermal	-52	-95	-115
CSP	67	238	313
PV	-35	-117	-191
Wind	214	139	106
Total	93	17	-56

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4) Swezey, Blair, R. Wiser, M. Bolinger, and E. Holt. 2001. *Growing the Green Power Market: Forecasting the Impacts of Customer Demand for Renewable Energy*. National Renewable Energy Laboratory, US Department of Energy. NREL/TP-620-30101.

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GPRA Representation of the Solar Energy Technologies Program

The Solar Program encompasses several technologies in thermal heat and electric markets. The solar buildings component is focused on developing low cost solar hot water and pool heaters to displace fossil-fueled alternatives. For electricity generation, photovoltaics are being improved for both distributed and central generation applications, and the Solar Program is working to accelerate PV adoption through the Million Solar Roofs Initiative. Concentrated Solar Power R&D has also been part of the Solar Program but is not included in the FY04 budget request except at a close-out level. As a result, CSP has not been included in the GPRA04 benefits estimates.

The GPRA benefits for solar water and pool heaters are represented within the residential module of NEMS-GPRA04. The solar water heater is a specific technology defined by its capital cost, O&M costs, and electrical usage. The baseline assumptions are modified to reflect the program goal of $1000 per unit and a backup fraction of 40 percent. The costs are changed for both new and replacement water heaters.

The pool heaters could not be modeled based on economics, because there is not a pool heating end-use within NEMS-GPRA04. In addition, it appears that the program is not really aimed at reducing the cost for solar pool heaters, but rather making them more acceptable by producing them in colors other than black. Therefore, the penetration rates and energy savings estimated by the program office were used to exogenously reduce water heating demand in the residential model.

Photovoltaic systems are represented using two methods. The capital and O&M costs were modified to reflect the program's goals, as reflected in the EERE/EPRI Technology Characteristics report. The regional capacity factors in the Baseline were already a similar to those in the EERE report, so they were left unchanged. In addition to competing on an economic basis with other electricity generation technologies, PVs may be constructed for their environmental benefits. The PERI Green Power Market Model was used to estimate the potential demand for renewable generation, including PVs, in response to the expanding green power markets in many places across the country. The projections for green power PV installations was combined with the Million Solar Roofs installation goals to determine the planned PV capacity additions that were incorporated into NEMS-GPRA04. All of the projected PV capacity for GPRA stems from the green power and MSRI additions.

Estimates of primary energy, oil, and carbon emissions savings result from direct displacement of fossil fuels for water and pool heating and from electricity demand reductions and PV generation. The savings associated with reduced electricity requirements depend on which types of generating plants were built in the Baseline case. Over time, the new facilities that are constructed in the Baseline become more efficient as gas combined cycle and combustion turbine technologies continue to improve. As a result the energy and emission savings decline per kilowatt-hour of renewable generation or electricity demand reductions. Energy expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. Energy savings from water and pool heaters also directly reduce energy expenditures.

FY04 GPRA Benefits Estimates for Solar (NEMS-GRPA04)			
	2005	**2010**	**2020**
Capacity (GW)	0.2	1.0	5.0
Generation (GWh)	0.4	1.7	8.9
Energy Savings (quads)	0.02	0.09	0.12
Oil Savings (quads)	0.00	0.01	0.01
Carbon Savings (MMT)	0.3	1.6	2.4
Energy Expenditure Savings (B2000$)	0.1	0.7	1.2

GPRA Representation of the Geothermal Technologies Program

The primary goal of the Geothermal Program is to reduce the cost of geothermal generation technologies, including both conventional and engineered geothermal source (EGS) systems. Measuring the GPRA benefits involves projecting the market share for these technologies based on their economic and environmental characteristics.

The NEMS-GPRA04 electricity sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (i.e. availability), the regional load requirements, and existing capacity resources. Geothermal capacity is treated in a unique manner due to the specific geographic nature of the resources. The model characterizes 51 individual sites of known hydrothermal geothermal resources, each with a set of capital and O&M costs. For the GPRA program case, an additional set of EGS sites were added to this slate.

The program was represented by reducing the capital and O&M costs for all hydrothermal geothermal sites, so that the average of the three lowest cost sites matched the program cost goals, as reflected in the EERE/EPRI Technology Characteristics report. Separate program technology goals were provided for the added EGS sites. In addition, the program was assumed to reduce the risk associated with new geothermal development, and the Baseline case limit on the size of annual developments per geothermal site was relaxed from 25 MW or 50 MW (depending on year) to 100 MW per year.

In addition to competing on an economic basis with other electricity generation technologies, geothermal capacity may be constructed for its environmental benefit. The PERI Green Power Market Model was used to estimate the potential demand for renewable generation, including geothermal, in response to the expanding green power markets in many places across the country. The projections for green power geothermal installations were incorporated into NEMS-GPRA04 as the planned capacity additions.

The primary energy, oil, and carbon emissions savings all stem from geothermal power displacing fossil-fueled generation sources that were built in the Baseline case. Over time, the new facilities that are constructed in the Baseline become more efficient as gas combined cycle and combustion turbine technologies continue to improve. As a result the energy and emission savings from the central grid decline per kilowatt-hour of renewable generation. Energy expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers.

The renewable programs have been modeled together, and the GPRA benefits are allocated to each proportional to their generation share.

FY04 GPRA Benefits Estimates for Geothermal (NEMS-GPRA04)			
	2005	2010	2020
Capacity (GW)	0.0	1.8	6.7
Generation (GWh)	0.4	14.8	54.6
Energy Savings (quads)	0.00	0.11	0.41
Oil Savings (quads)	0.00	0.01	0.02
Carbon Savings (MMT)	0.1	1.8	7.3
Energy Expenditure Savings (B2000$)	0.0	0.6	1.7

GPRA Representation of the Biomass Program

The Biomass Program is comprised of four major elements: bio-products, bio-power, black liquor gasification, and cellulosic ethanol. The methodology for computing the GPRA benefits estimates varied depending on the type of program and the relevant components of the NEMS-GPRA04 framework.

The bio-products component seeks to develop biomass based chemical products through innovative refining processes. The use of biomass would displace the traditional reliance on petroleum and natural gas as chemical feedstocks. Because of the multitude of products and the complexity of the chemicals industry, the NEMS-GPRA04 does not have sufficient detail within its representation of this industry to explicitly model bio-products. Energy savings were estimated off-line based on a simplified market penetration approach (Fisher Pry curves) by the program office. These results were then modified to reflect an assumption of 15 percent per year from 2010. This more conservative approach was used, because EERE does not yet have a market-based model of bioproducts growth. The energy savings by fuel are subtracted from industrial energy consumption projected by NEMS-GPRA04. The model is then used to compute the other GPRA benefits metrics of primary energy savings, carbon emission reductions, and energy expenditure savings.

The main thrust of the bio-power program is to develop and verify gasification technologies which enable the increased efficiency of bio-power generation from the current 20 percent efficiency to 30-35 percent efficiency. In estimating the GPRA benefits, the biomass generation capital and O&M costs were modified to reflect the program's goals, as reflected in the EERE/EPRI Technology Characteristics report. These costs and the biomass heat rates were very similar to those already in the Baseline, although the projected increase in biomass capacity is quite small in the Baseline. In addition to competing on an economic basis with other electricity generation technologies, biomass capacity may be constructed for its environmental benefits. The PERI Green Power Market Model was used to estimate the potential demand for renewable generation, including biomass, in response to the expanding green power markets in many places across the country. The projections for green power biomass installations were incorporated into NEMS-GPRA04 as the planned capacity additions. The majority of projected biomass generating capacity for GPRA stems from the green power additions.

Black liquor and hog fuel gasification systems use waste fuels produced by the pulp and paper industry. The goal of the program is to replace relatively inefficient existing boilers and cogeneration systems with a more efficient gasification process. The increased steam and electricity output from the same waste fuel input will displace fossil fueled steam and generation. The program office provided penetration rates for black liquor gasification based on a recently updated analysis of age-related boiler rebuilding and replacement rates, and an estimate of market share for BLGCC. As a percent of total stock (which takes into account both replacement rates and BLGCC market share), the BLGCC is projected to reach 0.3 percent in 2010, 23 percent in 2020 and 84 percent by 2035 of black liquor use. The BLGCC market share was applied to new stock as well in the assumption that the new black liquor production would likely be from expansions of existing mills. These estimates for the penetration rate of black liquor gasification (BLGG) and the technology efficiency were used to modify the biomass cogeneration efficiencies over time, because NEMS-GPRA04 does not perform an economic competition for the black liquor technologies. The primary energy savings result from reduced fossil fuel consumption for steam production and for reduced demand for electricity purchased from the grid.

Cellulosic ethanol program is aimed at reducing the cost of producing ethanol from biomass other than corn, which is the current feedstock. The cellulosic ethanol production costs are assumed to improve in the Baseline to a similar degree as expected to be achieved with the program funding, but the growth in projected production is assumed to be constrained. For the GPRA benefits estimates, these constraints are relaxed, so that cellulosic ethanol production equals the program goals (assuming other Baseline assumptions), which were developed using EERE's ethanol analytic model. NEMS-GPRA04 then

adjusts the overall level of ethanol purchased by accounting for the price impacts of competing sources of demand for biomass (e.g., gasification to produce electricity). Petroleum and fossil energy savings occur when the cellulosic ethanol displaces gasoline through enhanced blending. For these GPRA projections, a large portion of the cellulosic ethanol displaced corn ethanol which does not lead to energy savings. The cellulosic ethanol does lead to additional carbon emission savings through an off-line adjustment that takes into account for its lower life-cycle carbon emissions that is not incorporated in NEMS-GPRA04.

FY04 GPRA Benefits Estimates for Biomass (NEMS-GPRA04)			
	2005	**2010**	**2020**
Capacity (GW)	0.0	0.2	0.5
Generation (GWh)	0.3	1.3	3.7
Cellulosic Ethanol Production (Bil. gallons)	0.00	0.70	2.70
Energy Savings (quads)	0.05	0.11	0.45
Oil Savings (quads)	0.01	0.05	0.22
Carbon Savings (MMT)	0.7	2.0	9.7
Energy Expenditure Savings (B2000$)	0.0	0.4	3.2

GPRA Representation of the Hydrogen Program

The Hydrogen Program is targeted towards the introduction of fuel cells for both stationary and vehicular applications and the production of hydrogen at a reasonable price. The GPRA benefits estimates focus on gasoline and hydrogen fuel cells for vehicles. The Hydrogen Program has not yet established technology goals for stationary fuel cells, so benefits could not be computed. As a result, the benefits are underestimated. The production side of the program was represented as success in delivering hydrogen at $2.00 per gallon of gasoline equivalent (inclusive of taxes). As mid-term model, the NEMS-GPRA04 framework does not contain sufficient structure to analyze the production and delivery of hydrogen.

The fuel cell vehicles were modeled along with the FreedomCAR and Technologies Program. The gasoline and hydrogen fuel cell vehicle costs and efficiencies were modified to reflect the program goals (see the FreedomCAR Program description for more detail about the modeling of vehicle choice). The benefits associated with fuel cells were then attributed to the Hydrogen Program based on their relative efficiencies and their share of the displaced conventional gasoline vehicles VMT.

FY04 GPRA Benefits Estimates for Hydrogen* (NEMS-GPRA04)			
	2005	**2010**	**2020**
Energy Savings (quads)	0.00	0.00	0.11
Oil Savings (quads)	0.00	0.00	0.11
Carbon Savings (MMT)	0.0	0.1	2.2
Energy Expenditure Savings (B2000$)	0.0	0.1	2.0

* Does not yet include any benefits from stationary fuel cells.

GPRA Representation of the Distributed Energy and Electric Reliability (DEER) Program

The DEER Program encompasses many technologies and markets. The GPRA benefits were estimated by focusing on gas-fired combined heat and power (CHP) systems within building and industrial applications. Distributed generation (DG) applications that are motivated by the need for electric reliability will be primarily systems that produce only electricity and are used in back-up mode. We currently do not have the analytical tools to asses this market. Its absence from the benefits estimates may result in an underestimation of DG capacity, although not the energy or emission savings because these systems run for few hours per year and generally have similar or lower efficiencies than larger central station plants. To the extent that the central grid relies on DG for emergency power, avoided central station capacity may be underestimated as well.

Combined heat and power systems produce both useful thermal heat and electricity. Their economics depend on the amount of thermal heat needed at the site, the electricity usage at the site, the price of the input fuel, and the value of the electricity. If the end-use customer is making the investment, the electricity value will depend on the customer avoided purchases at the electricity retail price, and possibly the amount of excess electricity sold off-site at prevailing wholesale electricity prices. Using the average electricity price is a simplification that may overlook the requirement to continue paying some type of flat distribution charge, even though less electricity is purchased from the utility. If a vertically integrated electric utility is making the investment, the value is from avoided generation, transmission and distribution (T&D) costs. The distributed systems would be placed strategically in the grid to avoid T&D expansion costs.

The NEMS-GPRA04 framework uses a cashflow model to evaluate the DG technologies within the building sector. Assuming a 20 percent down payment, debt and interest payments are computed over a loan period of 20 years, along with associated taxes and tax benefits. Annual fixed maintenance costs are also included. Fuel costs are computed based on the delivered cost of natural gas and the technology efficiency. Netted against the fuel cost is the value of the useful waste heat produced as computed based on the delivered natural gas price, the thermal efficiency of the CHP system and the internal thermal load. The value of the electricity produced is then subtracted from these costs to determine the cash flow. The value of electricity is equal to the larger of the electricity produced (assuming 7125 hours of operation) and the internal electricity demand multiplied by the delivered electricity price. Any electricity produced in excess of internal needs is assumed to be sold to the grid at the wholesale power rate. The number of years until positive cash flow is reached determines the market share in new buildings[1]. The market share, as shown below, drops off sharply as the number of years increases to reflect the high rates of return generally expected for energy related projects by commercial building owners. The market share for existing buildings is assumed to be a fraction of the share for new.

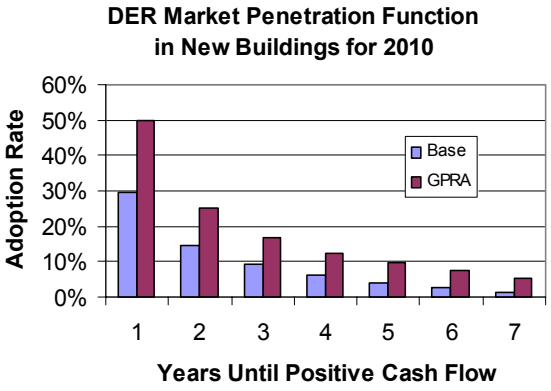
The analysis is performed for each of 11 building types in 9 regions. Even so, this is a fairly high level of aggregation, and therefore the model does not capture the niche markets that DG may fill. The current version also does not take into account the electricity and thermal seasonal and diurnal load shapes. It therefore may overestimate the value of both products by assuming that the CHP systems runs at full operation most of the time and that the electricity and heat can be used continuously. On the other hand, the DG systems are represented in discrete sizes, and some average building loads are too small to use the heat and electricity produced by the minimum 100 kW system, which makes the DG systems uneconomic.

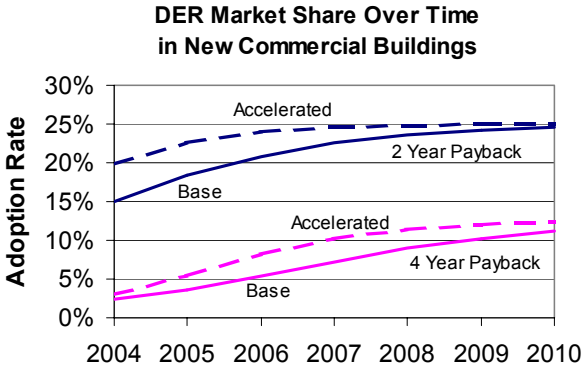
[1] With the accelerated depreciation positive cash is more likely to be reached sooner, although in some cases, the project can return to being uneconomic once the tax benefits are used.

The DEER program facilitates the development of the DG market by improving the technology characteristics (lowering costs, improving efficiency, and reducing environmental emissions) and by removing barriers to adoption and consumer acceptance. Thus the benefits are estimated based on the impact of improved technology and greater market penetration.

The Baseline used for the GPRA analysis already includes some DG technological advancement[2]. It was beyond the scope and schedule for this year's analysis to separate how much of the Baseline improvements might stem from government R&D efforts, and therefore should be removed. As a result, the GPRA benefits may be underestimated for the smaller commercial sector systems. To test the impact, we performed a sensitivity test taking out these improvements for the commercial sector CHP technologies. At the extreme of static year 2000 commercial CHO technology characteristics, DG capacity decreases by roughly 2 GW from the baseline. Although not in the AEO2002, the Baseline also assumes that small combined heat and power systems receive favorable tax treatment in terms of accelerated depreciation.

The DEER program's impact on consumer adoption rates was represented in several ways. The maximum market share that can be achieved in new buildings was increased from 30 percent in the Baseline to 50 percent in the GPRA case. The graph on the left below shows how the ultimate market share for new buildings varies by payback year. In addition, there is an adoption rate parameter that was accelerated to reflect faster market maturity in the GPRA case, as shown in the graph to the right.



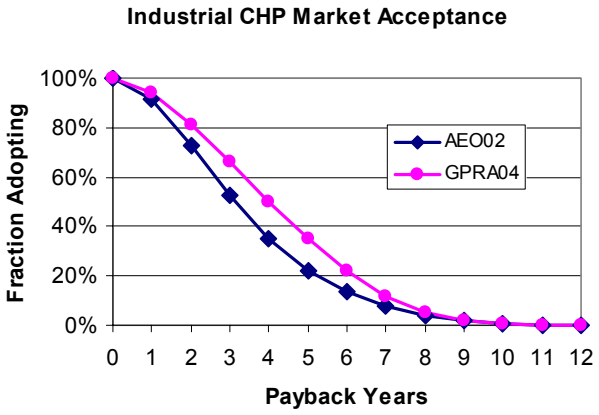


The market share for the existing building stock is tied to the market share computed for new buildings. The baseline assumption is that the existing stock share is one-fiftieth of the new share, while in the GPRA case the existing share is increased gradually from one-fiftieth to one-thirtieth of the new share. The share for the existing stock of buildings is considerably smaller than the market share for new buildings, because the entire existing stock will not make investments in CHP in a single year.

An economic competition for CHP systems is also performed in the industrial sector. All of the industrial CHP technologies improve over time in the GPRA case compared to the Baseline. The technology characteristics for the smaller internal combustion systems were take from the draft EERE Technology Characteristics report[3], while the larger system improvements are the intended EIA assumptions[4]. For the industrial CHP systems, as well as the for commercial sector, it was assumed that the DEER program will

[2] The Annual Energy Outlook 2002 assumes improved CHP technologies in the commercial sector. The input files for the industrial sector CHP systems show improvements as well, but a coding error led to these being unused and the technology characteristics remain at their year 2000 values.
[3] Add source.
[4] The assumptions in the AEO2002 input files as described in footnote 2.

enhance consumer acceptance and lower hurdles to adoption. This was reflected in the model by shifting the function determining the adoption rates as a function of payback years.



The incremental DG capacity and generation that results from this representation of the DEER program activities is shown in the table below, along with the projected total quantities. Of the 25 GW of incremental capacity, roughly half of the increase is expected from commercial building applications and half from generally larger industrial applications. The DG increase in the building sector is proportionally much larger, because there is currently relatively little DG in this sector.

In the Baseline case, the commercial sector is projected to satisfy roughly 3 percent of its total electricity demand with distributed CHP generation and the industrial sector 15 percent. With the DEER program, the share rises to 8 percent in the commercial sector and 20 percent in the industrial sector.

Distributed Combined Heat and Power						
	Capacity (GW)			Generation (BkWh)		
	2005	2010	2020	2005	2010	2020
Baseline						
Buildings	1.3	2.3	7.4	9	16	53
Industry	29.0	33.0	41.2	173	202	259
Total*	30.3	35.2	48.5	183	218	312
GPRA Case						
Buildings	2.1	5.4	20.3	15	39	146
Industry	30.5	37.3	53.2	184	233	347
Total*	32.6	42.7	73.6	199	272	493
Incremental						
Buildings	0.8	3.2	13.0	6	22	93
Industry	1.5	4.3	12.1	11	31	88
Total*	2.3	7.4	25.0	17	54	180

* excludes non-traditional large QF cogenerators

The DEER program benefits are projected within the integrated modeling framework, so that the impact of the program will be reflected in the rest of the energy system. As a result of increased investments in DG, electricity purchases from the commercial and industrial sectors are reduced, and additional electricity is sold wholesale to the grid. The central electricity generation industry responds by reducing production from the most expensive plants operating in each region, and over time by building fewer central station plants in the face of lower demand. Retirements are relatively unaffected, with only 2 GW

of additional capacity retired by 2020 in the GPRA case. Roughly 27 GW of central station investments are avoided by the additional DG. In the Baseline, roughly 90 percent of new utility and IPP additions from 2005 to 2020 are projected to be natural gas fired, so roughly 90 percent of those avoided investments are natural gas fired.

In total, distributed generation makes up roughly 12 percent of new capacity additions from 2005 to 2020 in the Baseline. This share increases to 18 percent in the GPRA case. For the later period of just 2015 to 2020, the distributed share rises from 16 percent in the Baseline to 26 percent in the GPRA case.

The energy and carbon emission reduction benefits that stem from distributed generation are computed as the decrease in traditional central station non-renewable energy consumption and associated carbon emissions net of the energy and emissions from the DG. The central station generation reductions are from a mix of existing plants and avoided new plants. Over time, the facilities that are used in the Baseline become more efficient as the gas combined cycle and combustion turbine technologies continue to improve. As a result the energy and emission savings from the central grid decline per kilowatt-hour. For example, in 2010 the average non-renewable energy avoided is at a rate of 9500 Btu/kWh, and by 2020 the value is reduced to 7800 Btu/kWh.

The benefits estimates for the High Temperature Superconductivity (HTS) program, another component of the DEER Program, were based on an analysis performed by a contractor for the program office. The estimates provided of kilowatt-hour reductions from HTS generators, transformers, cables, and motors were represented in NEMS by reducing T&D losses.

FY04 GPRA Benefits Estimates for DEER* (NEMS-GPRA04)			
	2005	**2010**	**2020**
Capacity (GW)	2.3	7.4	25.0
Generation (GWh)	16.7	53.8	180.1
Energy Savings (quads)	0.08	0.19	0.46
Oil Savings (quads)	0.00	0.01	0.02
Carbon Savings (MMT)	1.4	3.4	8.5
Energy Expenditure Savings (B2000$)	0.7	3.1	9.0

* Includes all credit for increased fuel cells although some sharing with the Hydrogen Program may occur.

GPRA Representation of the Wind and Hydropower Technologies Program

The wind component of the Wind and Hydropower Program seeks to reduce the cost and improve the performance of wind generation. The GPRA benefits are based primarily on projecting the market share for wind technologies based on their economic characteristics. The hydropower program goal is to reduce the environmental impact of hydroelectric facilities. Because this program is driven more by environmental than economic concerns, a program office estimate for the market penetration is the primary source for the GPRA benefits estimate.

The NEMS-GPRA04 electricity sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (i.e. availability), the regional load requirements, and existing capacity resources. Wind is characterized by three wind classes, although the best wind class is assumed to developed first within each region. Other key assumptions that can affect projections include a limit on the share of generation in each region that can be met with intermittent technologies. This was raised from a limit of 12 percent that is used by EIA in the AEO2002 to a limit of 30 percent based on experience in other countries and the program office expectations. Another assumption is how quickly the wind industry can expand before costs rise due to manufacturing bottlenecks. This was raised from 50 percent of installed wind capacity to 100 percent. Both of these assumptions were changed for the Baseline and GPRA cases, although they have no impact on the Baseline case.

The wind program was represented by reducing the capital and O&M costs for wind to match the program cost goals, as updated in the summer of 2001. In addition to competing on an economic basis with other electricity generation technologies, wind capacity may be constructed for its environmental benefit. The PERI Green Power Market Model was used to estimate the potential demand for renewable generation, including wind, in response to the expanding green power markets in many places across the country. The projections for green power wind installations were incorporated into NEMS-GPRA04 as the planned capacity additions.

The expectation of the hydropower program office is that future hydro capacity and generation will decrease due to environmental concerns as facilities undergo relicensing. The program goal is to develop hydro turbines that reduce fish mortality rates and therefore reduce the risk of these capacity reductions. The original Baseline projected relatively constant hydropower, implying that the technology was already assumed to be deployed or that the issue had not been examined. As a result, the final Baseline for GPRA was modified to reflect an estimate of hydro capacity and generation lost in the absence of the fish-friendly turbines. The GPRA program case then returned hydropower to the prior constant levels, and the benefits result from the increased hydro output.

Estimates of primary energy, oil, and carbon emissions savings stem from wind and hydropower displacing fossil-fueled generation sources that were built in the Baseline case. Over time, the new facilities that are constructed in the Baseline become more efficient as gas combined cycle and combustion turbine technologies continue to improve. As a result the energy and emission savings from the central grid decline per kilowatt-hour of renewable generation. Energy expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers.

The renewable programs have been modeled together, and the GPRA benefits are allocated to each proportional to their generation share.

FY04 GPRA Benefits Estimates for Wind & Hydropower (NEMS-GPRA04)			
	2005	2010	2020
Capacity (GW)	1.3	4.6	37.6
Generation (GWh)	5.0	17.3	156.5
Energy Savings (quads)	0.05	0.13	1.17
Oil Savings (quads)	0.01	0.01	0.07
Carbon Savings (MMT)	0.8	2.1	21.0
Energy Expenditure Savings (B2000$)	0.2	0.8	4.8

Projected Benefits of Federal Energy Efficiency and Renewable Energy Programs

FY 2004 Budget Request

Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

(Appendix E Only)

Prepared by the

National Renewable Energy Laboratory

April 2004 NREL/TP-620-36404

U.S. Department of Energy
Energy Efficiency and Renewable Energy
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Heavy Vehicle Technology Quality Metrics and GPRA Benefits Analysis Methodology Final Report (Revised)

Prepared for:

U.S. Department of Energy

Office of Planning, Budget Formulation &Analysis

July 2003

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Table of Contents

1.0 Introduction 1
2.0 Background 1
3.0 Approach 2
4.0 Results 7
5.0 References 13

Appendix

Heavy Vehicle Market Penetration Model (Version 3)

List of Exhibits

Exhibit 3-1: Heavy Vehicle Characteristics
Exhibit 3-2: Heavy Truck Benefits Analysis Models
Exhibit 3-3: HVMP Market Share Calculation Methodology
Exhibit 3-4: Heavy Vehicle Payback Period Market Distribution
Exhibit 3-5: Type 3 Heavy Vehicle Travel Distribution – Central Refueling
Exhibit 3-6: Type 3 Heavy Vehicle Travel Distribution – Non-Central Refueling
Exhibit 4-1: Summary Class 3-8 Energy and Emission Reductions
Exhibit 4-2: Market Penetration of Advanced Technologies in Heavy Vehicles
Exhibit 4-3: Heavy Vehicle (Class 3-8) Sales and Stocks of Advanced Technology Vehicles
Exhibit 4-4: Heavy Vehicle (Class 3-8) Energy Use
Exhibit 4-5: Heavy Vehicle (Class 3-8) CO_2 Emissions and Emission Reductions (1,000 tons)

1.0 Introduction:

This report describes the approach and findings of the Quality Metrics and GPRA assessment of the Heavy Vehicle Technologies Program of EERE. The scope of the effort included:

- Characterizing baseline and advanced technology vehicles for Class 3 – 6 and Class 7 and 8 trucks,
- Estimating the market potential of technologies that improve fuel efficiency and/or involve the use of alternative fuels,
- Determining the initial petroleum and greenhouse gas emissions reductions associated with the advanced technologies.

This report contains a description of the basis from which the analysis methodology was developed, a discussion of the models used to estimate market potential and initial or 'first order' benefits, and a presentation of the benefits estimated as a result of the adoption of the advanced technologies. These initial estimates, along with market penetration and other results are then modeled as part of the EERA-wide integrated analysis to provide final benefit estimates reported in the FY04 Budget Request.

2.0 Background:

This analysis of the initial benefits expected from achieving the Heavy Vehicle Technologies Program goals was developed based on three primary reference sources:

- Vehicle characteristics and use information—as obtained from the 1997 Vehicle Inventory and Use Survey (VIUS). This provides information on both vehicle performance characteristics, such as fuel economy; and also vehicle use patterns such as miles travelled per year. (Ref. 1)
- Truck operator investment requirements—as provided by a survey of Owner-Operators performed by the American Trucking Associations in 1995. (Ref. 2)
- Vehicle performance and cost characteristics for advanced technologies—as identified by the EERE Program Managers.

Important "background" information such as energy prices and baseline technology fuel economies are based on Annual Energy Outlook (Reference Case) prepared by the Energy Information Administration (Ref. 3).

The methodology involves a disaggregation of heavy vehicle types according to usage patterns. This has enabled the identification of the vehicle types that accumulate the greatest vehicle miles travelled; and therefore offer the best opportunity for economic return; i.e. pay-back on an investment in an energy conserving technology.

In prior years, the Heavy Vehicle Technologies Program had focused on one efficiency technology, the LE-55 Engine and one alternative fuels technology (natural gas). As a result, the market segmentation also identifies travel distributions for heavy vehicles that utilize central refueling sites, and those that do not, as it was judged that central refueling would be conducive to using an alternative fuel such as natural gas.

3.0 Approach:

3.1 Market Segmentation Analysis

"Heavy Vehicles" are defined in this analysis as including Classes 3 through 6 (Medium Trucks) and Classes 7 and 8 (Heavy Trucks). The Heavy Truck classes are further subdivided by end-use types. VIUS data were examined for all vehicles in use and vehicles two years old or less. The Heavy Truck vehicle market was parsed by the Analytic Team into three types that account for similar usage and annual vehicle mile usage patterns. The vehicle type segments are:

- Type 1 – multi-stop, step van, beverage, utility, winch, crane, wrecker, logging, pipe, garbage collection, dump, and concrete delivery;
- Type 2 – platform, livestock, auto transport, oil-field, grain, and tank;
- Type 3 – refrigerated van, drop frame van, open top van, and basic enclosed van.

The lower speed and 'stop and start' duty characteristics of Type 1 trucks greatly reduces the potential efficiency benefits of aerodynamic improvements in that sector. For similar reasons, fuel economy improvements due to advanced tires also would be limited for Type 1 vehicles.

As compared to long distance, over the road travel, Type 2 vehicles tend to be used in local or regional delivery; and, as a result, will realize little fuel economy benefit from aerodynamic improvements. Distances travelled by Type 2 vehicles are typically greater than Type 1, which makes them a somewhat better market sector for advanced tires.

In general, Type 3 vehicles are the best candidates for both tire and aerodynamic improvement technologies. Refueling characteristics; i.e. central-source refueling or non-central source also were considered as centrally-refueled vehicles would find an alternative fuel source more practical than vehicles that always refuel at road-side facilities.

Heavy vehicle characteristics are summarized in Exhibit 3-1. In the medium truck market segment (Classes 3 through 6), all vehicle types, with the exception of auto transport, on average travel about 20,000 miles per year. Heavy trucks, depending on type, travel an average of 40,000 miles to 92,000 miles per year. One of the more interesting findings was the significant difference in fuel economy among the vehicle types with Type 3 heavy vehicles exhibiting an average fuel economy nearly twice as high as Type 1 heavy vehicles (8.90 vs 4.55 MPG).

Exhibit 3-1: Heavy Vehicle Characteristics

Vehicle Type	Average Annual Miles (1)	Fuel Economy (MPG)	Percent Centrally Refueled (1)
Class 3-6	20,126	8.90	40.1%
Class 7 & 8 Type 1	40,043	4.55	59.8%
Class 7 & 8 Type 2	74,066	6.16	41.0%
Class 7 & 8 Type 3	92,434	8.90	42.0%

Note 1: Vehicles 2 years old or less

In addition to the market characterization, historical market penetration data was obtained from VIUS surveys for energy conserving technologies including radial tires, aerodynamic devices, and fan clutches. This data was utilized in the calibration of the rate of efficiency technology adoption in the model. (Ref. 1).

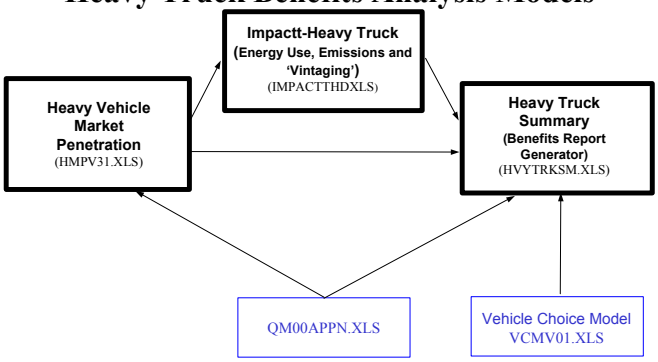
3.2 Heavy Vehicle Benefits Analysis Overview

Initial benefits estimates are generated through the linkage of three spreadsheet models:

- The Heavy Vehicle market Penetration (HVMP) model
- Integrated Market Penetration And Cost of Transportation Technologies (IMPACTT) model, and
- Heavy Truck Summary (HVS) model.

The relationship of these three models is indicated in Exhibit 3-2[1].

Exhibit 3-2:
Heavy Truck Benefits Analysis Models



Values for technology performance attributes and cost are input into the Heavy Vehicle Market Penetration (HVMP) model. This includes estimates for current technology fuel economy. Energy prices and projections used in the HVMP are linked to the values in the Quality Metrics Light Vehicle Results Model (QM00APPN.XLS). The HVMP model was developed to estimate the potential market impacts of new technologies on the medium and heavy truck market. The results generated by this model are:

- Market penetrations, in units of percent of new vehicles sold for each type and class of vehicle, and
- Composite fuel economy rating (new mpg) of the vehicles sold.

The market penetration results are supplied through a link to the Impactt-Heavy Truck model. This 'accounting' model calculates 'first order' energy savings, criteria and carbon pollution effects, and the rate of market penetration of the new technologies into the entire fleet of Class 3 through 8 trucks.

These interim results are linked to the Heavy Truck Summary model in which various reports of the energy, emissions, and economic benefits attributable to the use of the advanced technologies

[1] The Heavy Vehicle Market Penetration Model was developed as a collaborative effort, initially by John Maples of Oak Ridge National Laboratory (ORNL), with assistance from James Moore, of TA Engineering, Inc. Subsequent enhancements have been performed by Moore (TA Engineering).

IMPACTT was originally developed by Marianne Mintz, Argonne National Laboratory (ANL). The version of the model used for the Heavy Vehicle Analyses has been modified by Moore, et al, TA Engineering, with assistance from ANL.

The Heavy Truck Summary Model is a report generating spreadsheet. It was initially developed by Maples, and has subsequently been modified by Analysts at the National Renewable Energy Laboratory, and TA Engineering. Quality Metrics Light Vehicle Results Model was developed initially by John Maples, ORNL and since been modified extensively by Elyse Steiner, NREL and other NREL analysts.

The Vehicle Choice Model was developed as a collaborative effort of ANL, ORNL, and NREL analysts. It is based on a national survey of consumer attribute preferences conducted by ANL.

are calculated. Energy price factors and projections from the Annual Energy Outlook Reference Case are used by the Heavy Truck Summary model to calculate cost savings (Ref. 3).

3.3 Heavy Vehicle Market Penetration Model

Exhibit 3-3 explains the HVMP model's calculation method for Class 7 & 8, type 1 vehicles. The

Exhibit 3-3: HVMP Market Share Calculation Methodology

Spreadsheet Location	Description	Comments
Column A	Year	Identifies year for which values, calcuations and results are representative.
Columns B - F	Fuel Economy by Technology	Values are developed based on baseline technology mpg assumptions and efficiency ratios for advanced technologies.
Column G	Cost of Alternative Fuel in $/GGE	Links to Fuel Prices Page
Columns H - I	Calculates annual savings for 2 alternative technologies	For Advanced Diesel: (VMT(C10)x$/GGE/Baseline MPG - VMT x $/GGE/Adv. Diesel MPG)
Columns J - M	Calculates Net Present Value of Savings for 'Advanced Diesel'	Column J: 1 Year, K: 2 years, L: 3 years; M: 4 years
Columns N - Q	Calculates Net Present Value of Savings for 'Alternative Fuel Technology'	Column N: 1 Year, O: 2 years, P: 3 years; Q: 4 years
Columns R - U	If-then Statement to determine 'Cost Effectiveness Factor' (CEF)	If NPV of savings is > Cost of Technology, cell value is (cost - NPVSavings)/Cost; Otherwise cell value is 0. Columns are for paybacks of 1, 2, 3, and 4 years.
Column V	Technology purchase cost 'Alternative Fuel Technology'	Values are linked to Cost values on 'Inputs' page.
Column W - Z	Repeats calcuations in Columns R through U for 'Alternative Fuel Technology'	
Column AA	If-then Statement to determine 'Technology Adoption Factor' (TAF) for 'Advanced Diesel'	If 'Cost Effectiveness Factor' for Year 1 PB is 0, cell value = 100; Otherwise (100-((exp(1995 CE Factor-Current Yr. Factor) - 1)/10 x 100)
Column AB	Continuation of TAF Calculation for Year 1 Payback market	If AA<0, cell value is 1; Otherwise the Value is the same as AA.
Columns AC + AD	Repeat AA and AB for 2 year payback market	
Columns AE + AF	Repeat AA and AB for 3 year payback market	
Columns AG + AH	Repeat AA and AB for 4 year payback market	
Columns AI - AP	Repeat Columns AA through AH methodology for 'Alt. Fuel Technology'	
Column AQ	If-then statement. Start of Market Penetration for 'Advanced Diesel'	If AB = 100, then cell value is 0; Otherwise cell value is (1/(1+Abvalue/exp(-2 x Col. R CEF for 1 Year PB))
Column AR	Same as AQ, but for 2 year PB market.	
Column AS	Same as AQ, but for 3 year PB market.	
Column AT	Same as AQ, but for 4 year PB market.	
Column AU	Final, Step 1; Weighted average market penetration for year 1 through year 4 markets weighting factors	Weighting factors are based on ATA survey results and are listed at the top of Columns AQ-AT.
Column AV	Final, Step 2: Reduces Market Penetration to account for market penetration of 'Atl. Fuel Technology' and stay below 100% share.	=+(AU+(1-BA)*AU)/2
Columns AW - AZ	Same as columns AQ - AT for 'Alterntive fuel technology'.	
Column BA	Final, Step 1; For 'Alt. Fuel Tech.', weighted average market penetration for year 1 through year 4 markets weighting factors	
Column BB	Final, Step 2: Reduces Market Penetration to account for market penetration of 'Atl. Fuel Technology' and stay below 100% share.	
Columns BD - BN	Macro Results Array-Centrally Refueled Advanced Diesels	Central1 Macro results are printed in this part of spreadsheet
BO	Final Step 3: 'Advanced Diesel' (Centrally Refueled) Summation of %VMT that is centrally refueled for the VMT range (e.g. 0-19.9k)* % Market penetration for BD - BN array.	Results are linked to Market Penetration Page
Columns BQ - CA	Macro Results Array-Centrally Refueled Alternative Fuels	Macro results are printed in this part of spreadsheet. Alt Fuel technology only competes in Centrally Refueled Segment
CB	Final Step 3: 'Alt. Fuel' Summation of %VMT that is centrally refueled for the VMT range (e.g. 0-19.9k)* % Market penetration for BD - BN array.	Results are linked to Market Penetration Page
Columns CD - CN	Macro Results Array-Non Centrally Refueled Advanced Diesels	Macro results are printed in this part of spreadsheet
CO	Final Step 3: 'Advanced Diesel' (Non-centrally refueled) Summation of %VMT that is centrally refueled for the VMT range (e.g. 0-19.9k)* % Market penetration for BD - BN array.	Results are linked to Market Penetration Page

calculation method for the other 3 vehicle types and classes is highly analogous.

The HVMP model estimates market penetration based on cost effectiveness of the new technology. Cost effectiveness is measured as the incremental cost of the new technology less the discounted expected energy savings of that technology over a specified time period in relation to specified payback periods.

Exhibit 3-4 shows the payback distribution assumed in the HVMP model. This payback distribution was generated using data taken from a survey of 224 motor carriers conducted by the American Trucking Association. (Ref. 2) The survey found that, for example, 16.4% of the truck operators responding require a payback of one year on an investment.

Exhibit 3-4: Heavy Vehicle Payback Period Market Distribution

Number of Years	Percent of Motor Carriers
1	16.4%
2	61.7%
3	15.5%
4	6.4%

The new technology cost and the expected efficiency improvements are exogenous inputs. Energy savings are calculated using the following data and assumptions:

- Annual vehicle miles traveled;
- Fuel efficiency (mpg) without new technology (Ref. 1);
- Fuel efficiency (mpg) with new technology; these are specified as multipliers 'times' conventional mpg to limit the effort dedicated to estimating future conventional vehicle technology changes.
- Projected fuel price – diesel, ethanol, and CNG (Ref. 3);
- Incremental cost of new technology over time (economies of scale);
- Discount rate; and
- Payback period.

Values assigned for each are indicated in the Appendix, which contains a printout of the complete HVMP model.

In the HVMP model, the truck classes are segmented according to refueling location (i.e. central or multiple locations). The data analysis revealed that all vehicle segments have central refueling occurring at least forty percent (40.1%) of the time. As vehicles age, central refueling declines. This may be explained by the transition from larger fleet operations to small independent owner operators as centrally refueled vehicles age.

Eleven travel distance categories for medium trucks and twenty-one for heavy trucks are represented in the model. These categories were determined using travel distributions developed with the VIUS data by ORNL (Ref. 4).

Exhibits 3-5 and 3-6 show the distribution for Centrally and Non-Centrally refueled vehicles. Type 3 vehicles display the greatest amount of annual travel of all heavy vehicle classes. Centrally refueled vehicles travel less per year than non-centrally refueled vehicles. In the non-

centrally refueled vehicle segment, the majority of travel occurs from 100,000 to 140,000 miles per year. In the central refueling segment, the majority of travel occurs in a more even distribution between 20,000 and 140,000 miles per year.

Exhibit 3-5: Type 3 Heavy Vehicle Travel Distribution – Central Refueling

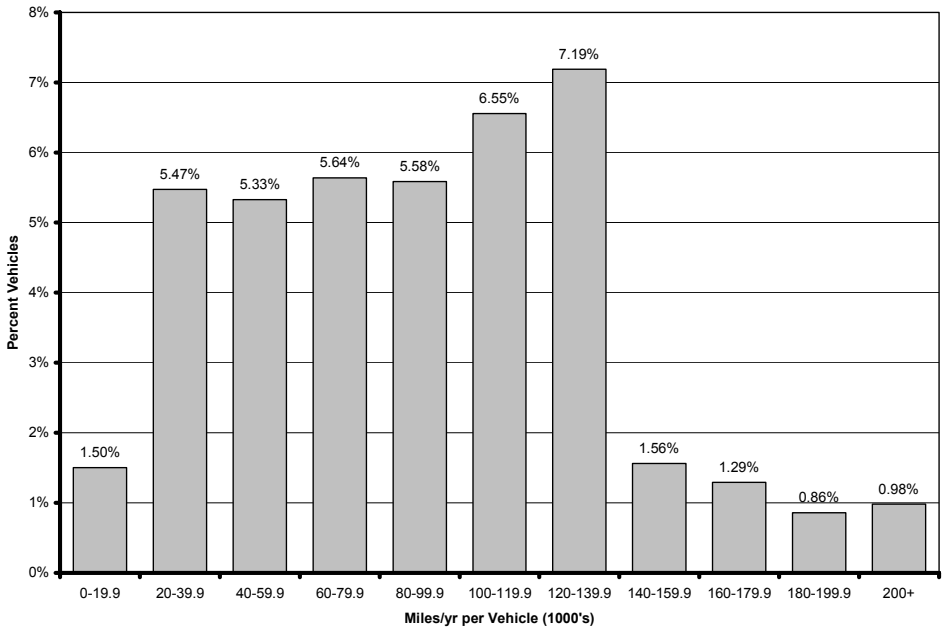
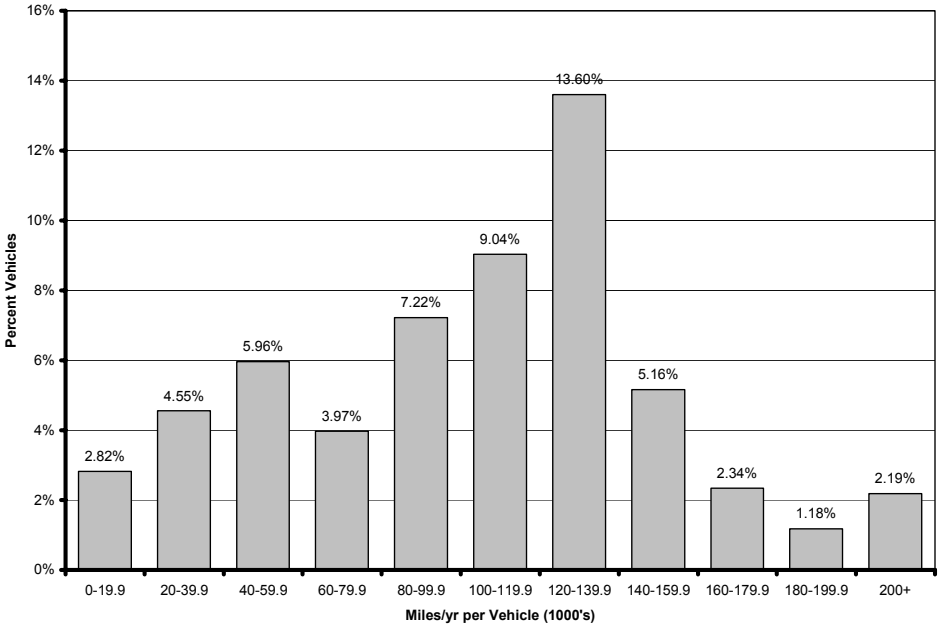


Exhibit 3-6: Type 3 Heavy Vehicle Travel Distribution – Non-Central Refueling



The technology performance assumptions and truck utilization patterns are used to determine payback performance for the advanced technologies in each type and class of vehicle. The model then calculates composite market penetrations and fuel economy values.

3.4 IMPACTT Heavy Truck

This model is a version of the IMPACTT tools developed by M. Mintz of ANL (Ref. 5). Fuel economies and market penetrations determined in HVMP are inputs to this model, which determines initial energy savings due to the expected market penetration of the advanced technologies in Medium and Heavy Vehicles. The model also has the capability of estimating criteria emissions savings, and carbon reduction. In addition, it projects the portion of the Medium and Heavy Vehicle *fleet* that are advanced technologies.

3.3 Heavy Truck Summary

This report generator provides nine tables of the first order benefits for the period covering 2000 through 2030.

Specific results are generated for the following:

- Class 3 – 8 Energy and Emissions Reductions
- Technology Market Penetrations
- Sales and Stocks of Advanced Technology Vehicles
- Heavy Vehicle Energy Use—including a breakdown by Class and Technology
- CO_2 Emissions and Emissions Reduction
- NOx, CO, and Non-methane Hydrocarbon Emissions and Emission Reductions, and
- Value of Emissions Reductions (both Carbon and Criteria Pollutants)

4.0 Results

Principal results for QM04 analysis are provided in Exhibits 4-1 through 4-5 below.

These are reproduced from the Heavy Truck Summary Model.

Exhibit 4-1: Summary Class 3 - 8 Energy and Emission Reductions

	Energy Reduction			Alternative	Petroleum	Carbon Reduction						Energy Cost Savings			Incremental
	Total	Class 3-6	Class 7-8	Fuel Use	Reduction	Total	Class 3-6	Class 7-8	Emission Reductions (1000 tons)			Total	Class 3-6	Class 7-8	Vehicle Cost
Year	mmb/d	mmb/d	mmb/d	mmb/d	mmb/d	(MMTCe)	(MMTCe)	(MMTCe)	NOx	CO	NMHC	million 2000$	million 2000$	million 2000$	million 2000$
2000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
2001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
2002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00	0.00	0.00	0.00
2003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.000	0.06	0.06	0.00	0.25
2004	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.011	0.015	0.003	0.53	0.47	0.06	2.51
2005	0.001	0.000	0.001	0.000	0.001	0.047	0.006	0.041	0.163	0.186	0.041	21.66	2.72	18.94	169.12
2006	0.003	0.000	0.002	0.000	0.003	0.106	0.006	0.099	0.298	0.343	0.098	50.03	3.01	47.02	88.80
2007	0.004	0.000	0.004	0.000	0.004	0.190	0.011	0.179	0.547	0.612	0.176	93.96	5.37	88.59	115.20
2008	0.007	0.000	0.007	0.000	0.007	0.301	0.017	0.285	0.877	0.968	0.279	150.31	8.29	142.02	147.67
2009	0.011	0.001	0.010	0.000	0.011	0.448	0.024	0.424	1.310	1.441	0.413	224.63	12.02	212.61	188.23
2010	0.015	0.001	0.014	0.000	0.015	0.641	0.034	0.607	1.882	2.064	0.591	325.54	17.21	308.33	239.63
2011	0.021	0.001	0.020	0.000	0.021	0.897	0.047	0.850	2.640	2.892	0.827	458.20	23.97	434.23	305.83
2012	0.029	0.001	0.027	0.000	0.029	1.205	0.062	1.142	3.547	3.881	1.108	611.64	31.61	580.03	358.01
2013	0.037	0.002	0.036	0.000	0.037	1.582	0.081	1.501	4.633	5.068	1.447	803.67	41.03	762.65	420.82
2014	0.048	0.002	0.046	0.000	0.048	2.048	0.104	1.943	5.949	6.514	1.865	1,032.99	52.63	980.36	493.11
2015	0.062	0.003	0.059	0.000	0.062	2.629	0.136	2.493	7.585	8.325	2.393	1,330.07	68.81	1,261.26	574.61
2016	0.076	0.004	0.072	0.000	0.076	3.191	0.171	3.020	9.145	10.079	2.916	1,608.70	86.12	1,522.58	535.76
2017	0.088	0.005	0.083	0.000	0.088	3.725	0.208	3.517	10.590	11.733	3.422	1,871.27	104.41	1,766.86	535.23
2018	0.100	0.006	0.094	0.000	0.100	4.234	0.248	3.986	11.925	13.294	3.914	2,128.23	124.52	2,003.71	544.79
2019	0.112	0.007	0.105	0.000	0.112	4.712	0.294	4.418	13.136	14.767	4.402	2,355.96	146.93	2,209.03	561.74
2020	0.122	0.008	0.114	0.000	0.122	5.159	0.345	4.814	14.203	16.126	4.875	2,581.52	172.51	2,409.01	592.70
2021	0.138	0.010	0.128	0.000	0.138	5.813	0.423	5.390	15.889	18.234	5.575	2,946.19	214.54	2,731.66	746.06
2022	0.158	0.012	0.146	0.000	0.158	6.684	0.524	6.160	18.165	21.036	6.482	3,430.39	269.01	3,161.38	865.19
2023	0.185	0.015	0.170	0.000	0.185	7.806	0.646	7.160	21.092	24.590	7.607	4,056.63	335.83	3,720.79	974.27
2024	0.218	0.019	0.199	0.000	0.218	9.207	0.797	8.411	24.831	29.090	9.013	4,843.96	419.04	4,424.91	1,061.82
2025	0.257	0.023	0.234	0.000	0.257	10.858	0.991	9.867	29.459	34.705	10.782	5,781.88	527.76	5,254.12	1,096.60
2026	0.295	0.028	0.267	0.000	0.295	12.449	1.176	11.273	33.947	40.107	12.456	6,717.58	634.40	6,083.18	1,000.14
2027	0.332	0.032	0.300	0.000	0.332	14.015	1.365	12.650	38.466	45.552	14.132	7,662.34	746.52	6,915.82	1,022.08
2028	0.368	0.037	0.331	0.000	0.368	15.549	1.560	13.989	43.018	51.037	15.809	8,611.45	863.88	7,747.57	1,043.74
2029	0.403	0.042	0.362	0.000	0.403	17.037	1.759	15.278	47.447	56.408	17.449	9,556.15	986.59	8,569.55	1,065.46
2030	0.437	0.046	0.390	0.000	0.437	18.449	1.961	16.488	51.507	61.408	18.984	10,479.51	1,113.74	9,365.77	1,085.18
Cumulative Total From Year 2000 to Year															
2005	0.001	0.000	0.001	0.000	0.001	0.048	0.007	0.041	0.175	0.204	0.044	22.25	3.25	19.00	171.89
2010	0.041	0.002	0.039	0.000	0.041	1.733	0.099	1.635	5.089	5.632	1.600	866.72	49.15	817.56	951.40
2015	0.239	0.013	0.226	0.000	0.239	10.093	0.529	9.565	29.442	32.311	9.239	5,103.29	267.20	4,836.09	3,103.79
2020	0.737	0.042	0.694	0.000	0.737	31.114	1.794	29.320	88.441	98.310	28.768	15,648.97	901.68	14,747.28	5,874.01

Exhibit 4-2: Market Penetration of Advanced Technologies in Heavy Vehicles

	Class 7-8 Type 1		Class 7-8 Type 2		Class 7-8 Type 3		CLASS 7-8 Final		CLASS 3-6 Final	
Year	CURRENT	ENHANCED	CURRENT	ENHANCED	CURRENT	ENHANCED	CURRENT	ENHANCED	CURRENT	ENHANCED
2000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2001	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2002	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2003	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2004	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2005	0.2%	0.0%	1.2%	0.0%	2.4%	0.0%	1.8%	0.0%	0.3%	0.0%
2006	0.3%	0.0%	1.7%	0.0%	3.3%	0.0%	2.4%	0.0%	0.4%	0.0%
2007	0.4%	0.0%	2.3%	0.0%	4.4%	0.0%	3.2%	0.0%	0.5%	0.0%
2008	0.5%	0.0%	3.0%	0.0%	5.6%	0.0%	4.1%	0.0%	0.6%	0.0%
2009	0.7%	0.0%	3.9%	0.0%	7.1%	0.0%	5.2%	0.0%	0.8%	0.0%
2010	0.9%	0.0%	5.1%	0.0%	9.1%	0.0%	6.7%	0.0%	1.0%	0.0%
2011	1.2%	0.0%	6.6%	0.0%	11.8%	0.0%	8.7%	0.0%	1.3%	0.0%
2012	1.6%	0.0%	8.3%	0.0%	14.5%	0.0%	10.8%	0.0%	1.6%	0.0%
2013	2.2%	0.0%	10.7%	0.0%	17.9%	0.0%	13.5%	0.0%	2.0%	0.0%
2014	2.9%	0.0%	13.8%	0.0%	22.4%	0.0%	17.0%	0.0%	2.7%	0.0%
2015	2.6%	0.0%	18.4%	0.0%	27.8%	0.0%	21.2%	0.0%	3.6%	0.0%
2016	4.2%	0.0%	18.1%	0.0%	27.6%	0.0%	21.3%	0.0%	4.0%	0.0%
2017	4.1%	0.0%	18.0%	0.0%	27.5%	0.0%	21.2%	0.0%	4.4%	0.0%
2018	4.1%	0.0%	17.9%	0.0%	27.4%	0.0%	21.1%	0.0%	4.8%	0.0%
2019	4.1%	0.0%	17.9%	0.0%	27.3%	0.0%	21.1%	0.0%	5.6%	0.0%
2020	4.2%	0.0%	18.2%	0.0%	27.7%	0.0%	21.4%	0.0%	6.4%	0.0%
2025	18.6%	0.0%	54.7%	0.0%	66.5%	0.0%	55.3%	0.0%	14.6%	0.0%
2030	20.1%	0.0%	56.7%	0.0%	69.8%	0.0%	58.0%	0.0%	16.0%	0.0%

Exhibit 4-3: Heavy Vehicle (Class 3-8) Sales and Stocks of Advanced Technology Vehicles

	SALES				STOCKS				STOCKS (Percent of Total)			
	3-6		7&8		3-6		7&8		3-6		7&8	
Year	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced
2000	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
2001	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
2002	0	0	0	0	0	0	0	0	0.0%	0.0%	0.0%	0.0%
2003	14	0	0	0	14	0	0	0	0.0%	0.0%	0.0%	0.0%
2004	97	0	23	0	111	0	23	0	0.0%	0.0%	0.0%	0.0%
2005	566	0	5,810	0	677	0	5,833	0	0.0%	0.0%	0.1%	0.0%
2006	821	0	8,223	0	1,496	0	14,038	0	0.0%	0.0%	0.3%	0.0%
2007	1,140	0	11,214	0	2,630	0	25,199	0	0.1%	0.0%	0.5%	0.0%
2008	1,508	0	15,201	0	4,125	0	40,288	0	0.1%	0.0%	0.7%	0.0%
2009	2,008	0	20,538	0	6,110	0	60,616	0	0.1%	0.0%	1.1%	0.0%
2010	2,787	0	27,723	0	8,859	0	87,971	0	0.2%	0.0%	1.5%	0.0%
2011	3,781	0	37,752	0	12,576	0	125,080	0	0.3%	0.0%	2.1%	0.0%
2012	4,665	0	47,413	0	17,139	0	171,380	0	0.4%	0.0%	2.8%	0.0%
2013	6,013	0	59,932	0	22,996	0	229,584	0	0.5%	0.0%	3.6%	0.0%
2014	7,880	0	75,881	0	30,646	0	302,881	0	0.6%	0.0%	4.6%	0.0%
2015	10,715	0	95,903	0	41,026	0	395,033	0	0.8%	0.0%	5.9%	0.0%
2016	12,240	0	97,361	0	52,790	0	487,080	0	1.0%	0.0%	7.1%	0.0%
2017	13,406	0	96,857	0	65,539	0	576,638	0	1.2%	0.0%	8.2%	0.0%
2018	14,954	0	98,191	0	79,606	0	665,075	0	1.5%	0.0%	9.2%	0.0%
2019	17,740	0	100,285	0	96,173	0	752,627	0	1.7%	0.0%	10.2%	0.0%
2020	20,908	0	105,159	0	115,554	0	841,520	0	2.0%	0.0%	11.1%	0.0%
2021	24,915	0	134,262	0	138,510	0	955,365	0	2.4%	0.0%	12.4%	0.0%
2022	29,980	0	169,837	0	166,008	0	1,100,015	0	2.8%	0.0%	14.1%	0.0%
2023	34,504	0	210,610	0	197,406	0	1,280,315	0	3.3%	0.0%	16.1%	0.0%
2024	40,834	0	253,636	0	234,395	0	1,497,944	0	3.9%	0.0%	18.5%	0.0%
2025	51,498	0	289,206	0	281,184	0	1,744,877	0	4.6%	0.0%	21.1%	0.0%
2030	60,253	0	321,557	0	522,781	0	2,962,059	0	8.1%	0.0%	32.7%	0.0%

Exhibit 4-4: Heavy Vehicle (Class 3-8) Energy Use

Year	Base Case Energy Use, Trillion BTUs			Class 3-6 Technology Energy Use, Trillion BTUs				Class 7&8 Technology Energy Use, Trillion BTUs				Current & Enhanced Energy Use	Energy Savings	Energy Savings by Program, Trillion BTUs	
	Class 3-6	Class 7-8	Total	Class 3-6 Conv.	Current Program	Enhanced Program	Total	Class 7-8 Conv.	Current Program	Enhanced Program	Total	Trillion BTUs	Trillion BTUs	Current Program	Enhanced Program
2000															
2001	835.8	3,903.2	4,739.0	835.8	0.0	0.0	835.8	3,903.2	0.0	0.0	3,903.2	4,739.0	0.0	0.0	0.0
2002	840.6	4,069.2	4,909.7	840.6	0.0	0.0	840.6	4,069.2	0.0	0.0	4,069.2	4,909.7	0.0	0.0	0.0
2003	855.6	4,238.5	5,094.1	855.6	0.0	0.0	855.6	4,238.5	0.0	0.0	4,238.5	5,094.1	0.0	0.0	0.0
2004	864.7	4,361.5	5,226.2	864.7	0.0	0.0	864.7	4,361.5	0.0	0.0	4,361.5	5,226.2	0.1	0.1	0.0
2005	874.8	4,438.8	5,313.6	874.5	0.0	0.0	874.5	4,430.5	6.3	0.0	4,436.8	5,311.3	2.3	2.3	0.0
2006	876.1	4,479.5	5,355.6	875.5	0.3	0.0	875.8	4,459.4	15.1	0.0	4,474.5	5,350.3	5.3	5.3	0.0
2007	882.8	4,543.3	5,426.1	881.8	0.5	0.0	882.3	4,507.3	27.1	0.0	4,534.3	5,416.6	9.5	9.5	0.0
2008	895.3	4,613.4	5,508.7	893.7	0.8	0.0	894.5	4,556.3	42.8	0.0	4,599.2	5,493.6	15.1	15.1	0.0
2009	910.5	4,706.9	5,617.4	908.2	1.1	0.0	909.3	4,621.9	63.7	0.0	4,685.6	5,594.9	22.4	22.4	0.0
2010	928.4	4,808.6	5,737.1	925.2	1.6	0.0	926.7	4,687.2	91.0	0.0	4,778.2	5,705.0	32.1	32.1	0.0
2011	949.7	4,930.5	5,880.2	945.2	2.2	0.0	947.4	4,760.4	127.5	0.0	4,887.9	5,835.3	45.0	45.0	0.0
2012	967.3	5,032.5	5,999.8	961.3	2.9	0.0	964.2	4,804.1	171.2	0.0	4,975.3	5,939.5	60.4	60.4	0.0
2013	981.0	5,141.1	6,122.1	973.2	3.8	0.0	977.0	4,840.7	225.2	0.0	5,065.9	6,042.9	79.3	79.3	0.0
2014	994.6	5,248.2	6,242.8	984.4	5.0	0.0	989.4	4,858.5	292.2	0.0	5,150.8	6,140.2	102.6	102.6	0.0
2015	1,009.3	5,359.5	6,368.9	996.0	6.5	0.0	1,002.5	4,858.9	375.7	0.0	5,234.6	6,237.1	131.8	131.8	0.0
2016	1,024.7	5,472.7	6,497.5	1007.9	8.3	0.0	1,016.2	4,865.1	456.2	0.0	5,321.4	6,337.5	159.9	159.9	0.0
2017	1,042.3	5,595.1	6,637.4	1021.7	10.2	0.0	1,031.9	4,885.8	533.0	0.0	5,418.8	6,450.7	186.7	186.7	0.0
2018	1,060.6	5,719.7	6,780.3	1,035.9	12.3	0.0	1,048.2	4,913.6	606.4	0.0	5,519.9	6,568.1	212.2	212.2	0.0
2019	1,079.0	5,838.6	6,917.6	1,049.6	14.7	0.0	1,064.3	4,942.0	675.1	0.0	5,617.1	6,681.4	236.2	236.2	0.0
2020	1,091.6	5,942.9	7,034.5	1,056.8	17.4	0.0	1,074.3	4,962.1	739.5	0.0	5,701.6	6,775.9	258.6	258.6	0.0
2021	1,134.1	6,088.3	7,222.4	1,091.7	21.1	0.0	1,112.9	4,986.0	832.2	0.0	5,818.2	6,931.1	291.4	291.4	0.0
2022	1,178.1	6,238.0	7,416.1	1,126.3	25.6	0.0	1,151.8	4,973.5	955.8	0.0	5,929.3	7,081.1	335.0	335.0	0.0
2023	1,224.2	6,391.3	7,615.5	1,161.0	30.7	0.0	1,191.8	4,916.4	1,116.1	0.0	6,032.5	7,224.2	391.3	391.3	0.0
2024	1,272.0	6,549.0	7,821.0	1,195.1	37.0	0.0	1,232.1	4,812.1	1,315.4	0.0	6,127.4	7,359.5	461.5	461.5	0.0
2025	1,321.5	6,709.2	8,030.7	1,226.8	45.0	0.0	1,271.8	4,669.2	1,545.5	0.0	6,214.7	7,486.5	544.2	544.2	0.0
2026	1,344.4	6,840.6	8,184.9	1,233.1	52.3	0.0	1,285.4	4,507.9	1,767.7	0.0	6,275.5	7,561.0	624.0	624.0	0.0
2027	1,367.8	6,974.5	8,342.3	1,239.9	59.5	0.0	1,299.4	4,355.8	1,984.7	0.0	6,340.5	7,639.9	702.5	702.5	0.0
2028	1,391.6	7,111.1	8,502.7	1,246.8	66.6	0.0	1,313.4	4,214.9	2,195.1	0.0	6,410.0	7,723.3	779.4	779.4	0.0
2029	1,415.8	7,250.5	8,666.3	1,254.1	73.6	0.0	1,327.7	4,086.3	2,398.4	0.0	6,484.7	7,812.4	853.9	853.9	0.0
2030	1,440.5	7,392.6	8,833.1	1,261.7	80.5	0.0	1,342.2	3,973.1	2,593.1	0.0	6,566.2	7,908.4	924.7	924.7	0.0
Cumulative Total From Year 2000 to Year															
2005	4,271	21,011	25,283	4,271	0	0	4,271	21,011	6	0	21,009	25,280	2	2	0
2010	8,765	44,163	52,928	8,755	4	0	8,760	44,163	246	0	44,081	52,841	87	87	0
2015	13,667	69,875	83,541	13,615	25	0	13,640	69,875	1,438	0	69,395	83,035	506	506	0
2020	18,965	98,444	117,409	18,787	88	0	18,875	98,444	4,448	0	96,974	115,849	1,559	1,559	0
2025	25,095	130,420	155,514	24,588	247	0	24,835	130,420	10,213	0	127,096	151,932	3,583	3,583	0
2030	32,055	165,989	198,044	30,824	580	0	31,403	165,989	21,152	0	159,173	190,577	7,467	7,467	0

Exhibit 4-5: Heavy Vehicle (Class 3-8) CO2 Emissions and Emission Reductions (1,000 tons)

	OPERATIONAL EMISSIONS			UPSTREAM EMISSIONS					
	Reduction			Reduction			TOTAL REDUCTION		
Year	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total	CLS 3-6	CLS 7&8	Total
2000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	0.5	0.0	0.5	0.0	0.0	0.0	0.5	0.0	0.5
2004	3.9	0.5	4.4	0.0	0.0	0.0	3.9	0.5	4.4
2005	22.9	163.0	185.9	0.0	0.0	0.0	22.9	163.0	185.9
2006	24.4	395.9	420.3	0.0	0.0	0.0	24.4	395.9	420.3
2007	41.8	712.7	754.4	0.0	0.0	0.0	41.8	712.7	754.4
2008	64.1	1,132.2	1,196.3	0.0	0.0	0.0	64.1	1,132.2	1,196.3
2009	92.4	1,686.5	1,779.0	0.0	0.0	0.0	92.4	1,686.5	1,779.0
2010	130.8	2,414.4	2,545.2	0.0	0.0	0.0	130.8	2,414.4	2,545.2
2011	181.2	3,383.3	3,564.5	0.0	0.0	0.0	181.2	3,383.3	3,564.5
2012	240.4	4,545.8	4,786.2	0.0	0.0	0.0	240.4	4,545.8	4,786.2
2013	311.7	5,973.6	6,285.3	0.0	0.0	0.0	311.7	5,973.6	6,285.3
2014	402.7	7,734.1	8,136.9	0.0	0.0	0.0	402.7	7,734.1	8,136.9
2015	525.0	9,921.5	10,446.5	0.0	0.0	0.0	525.0	9,921.5	10,446.5
2016	659.2	12,017.8	12,676.9	0.0	0.0	0.0	659.2	12,017.8	12,676.9
2017	801.9	13,996.1	14,798.0	0.0	0.0	0.0	801.9	13,996.1	14,798.0
2018	955.7	15,863.7	16,819.4	0.0	0.0	0.0	955.7	15,863.7	16,819.4
2019	1,133.6	17,583.9	18,717.5	0.0	0.0	0.0	1,133.6	17,583.9	18,717.5
2020	1,329.5	19,158.8	20,488.4	0.0	0.0	0.0	1,329.5	19,158.8	20,488.4
2021	1,632.9	21,449.5	23,082.3	0.0	0.0	0.0	1,632.9	21,449.5	23,082.3
2022	2,022.6	24,513.0	26,535.6	0.0	0.0	0.0	2,022.6	24,513.0	26,535.6
2023	2,494.7	28,494.0	30,988.7	0.0	0.0	0.0	2,494.7	28,494.0	30,988.7
2024	3,076.0	33,472.4	36,548.4	0.0	0.0	0.0	3,076.0	33,472.4	36,548.4
2025	3,828.4	39,265.5	43,093.9	0.0	0.0	0.0	3,828.4	39,265.5	43,093.9
2030	7,584.8	65,618.4	73,203.2	0.0	0.0	0.0	7,584.8	65,618.4	73,203.2
Cumulative Total From Year 2000 to Year									
2005	27.3	163.5	190.8	0.0	0.0	0.0	27.3	163.5	190.8
2010	380.7	6,505.3	6,886.1	0.0	0.0	0.0	380.7	6,505.3	6,886.1
2015	2,041.8	38,063.6	40,105.3	0.0	0.0	0.0	2,041.8	38,063.6	40,105.3
2020	6,921.6	116,683.9	123,605.5	0.0	0.0	0.0	6,921.6	116,683.9	123,605.5
2025	19,976.2	263,878.2	283,854.4	0.0	0.0	0.0	19,976.2	263,878.2	283,854.4
2030	47,944.4	528,771.1	576,715.5	0.0	0.0	0.0	47,944.4	528,771.1	576,715.5

References

1. 1997 Vehicle Inventory and Use Survey, EC97TV-US U.S. Bureau of the Census, Washington, D. C., 1999.
2. 1997 Return on Investment Survey, American Trucking Association, Arlington Va., 1997.
3. "Annual Energy Outlook 2002, With Projections to 2020," Energy Information Agency, Department of Energy, Washington, D. C., Publication DOE/EIA-0383 (2002). (Website address: http://www.eia.doe.gov/bookshelf.html *(Library/Archives-Forecasting)*.
4. Personal Communication with Stacy Davis, ORNL, November 2001
5. Mintz, M. M. and Saricks, "IMPACTT5A Model: Enhancements and modifications since December 1994," Center for Transportation Research, Energy Systems Division, Argonne National Laboratory, Argonne, Illinois, September 1998.

Appendix

Overview of Heavy Vehicle Market Penetration Model (HVMP)

The HVMP is a spreadsheet model that currently operates in Excel (Office 2000 and associated versions). It consists of nine spreadsheets linked to other models. It is operated by user specifying inputs and then initiating macros that perform iterative calculations to determine market shares by technology in percents of new vehicle sales. The spreadsheets are reproduced on the following pages. In some cases the spreadsheets take up several pages. These are presented in sequence with an arrow to indicate the relationship of the current page to the following page.

1. **Inputs**-user specifies incremental technology cost and relative fuel efficiency for current and advanced technology(ies). These inputs are specified by year to 2035 and separately for Class 7 & 8 and Classes 3 through 6 vehicles.
2. **Fuel Prices**—array of fuel price information. Typically linked to other AEO-source files.
3. **Market Data (6 pages)**—Distribution of vehicle usage patterns from 1997 VIUS
4. **Type 1 (7 pages)**—Contains macro in which calculations are performed to determine market distribution of conventional and new technologies for "Type 1" Class 7 and 8 vehicles. Calculations are performed separately for centrally refueled and non-centrally refueled vehicles.
5. **Type 2 (6 pages)**—Contains macro in which calculations are performed to determine market distribution of conventional and new technologies for "Type 2" Class 7 and 8 vehicles. Calculations are performed separately for centrally refueled and non-centrally refueled vehicles.
6. **Type 3 (6 pages)**—Contains macro in which calculations are performed to determine market distribution of conventional and new technologies for "Type 3" Class 7 and 8 vehicles. Calculations are performed separately for centrally refueled and non-centrally refueled vehicles.
7. **Med (6 pages)**—Contains macro in which calculations are performed to determine market distribution of conventional and new technologies for "Medium", i.e., Class 3 through 6 vehicles. Calculations are performed separately for centrally refueled and non-centrally refueled vehicles.
8. **New MPG (2 pages)**—Shows the effect of new technology penetrations on the fleet fuel economy by vehicle class.
9. **Market Penetration (1 page)**—Summarizes the market penetration of new technologies in units of new vehicle sales percentage. Lists market shares for each Class 7 & 8 vehicle type, Class 7 & 8 composite and Classes 3 through 6 (composite).

Inputs

COST AND EFFICIENCY ESTIMATES FOR HEAVY VEHICLE ADVANCED TECHNOLOGIES

Combined Run: Current and Enhanced Program

Cost: Incremental vehicle price of added technology

Efficiency Ratio: Ratio of advanced vehicle fuel mpg compared to conventional vehicle

(Run uses base fuel economies from S. Davis VIUS Analysis)

	CLASS 7 & 8					CLASS 3-6				
	CURRENT		ENHANCED				CURRENT		ENHANCED	
Year	Cost	Efficiency Ratio	Cost	Efficiency Ratio		Year	Cost	Efficiency Ratio	Cost	Efficiency Ratio
1995	100,000	0.01	100,000	1.00		1995	20,000	1.00	100,000	1.00
1996	100,000	0.21	100,000	1.00		1996	19,000	1.00	100,000	1.00
1997	100,000	0.41	100,000	1.00		1997	18,000	1.00	100,000	1.00
1998	100,000	0.60	100,000	1.00		1998	17,000	1.00	100,000	1.00
1999	100,000	0.80	100,000	1.00		1999	16,000	1.00	100,000	1.00
2000	100,000	1.00	100,000	1.00		2000	15,000	1.00	100,000	1.00
2001	82,000	1.09	100,000	1.00		2001	14,000	1.20	100,000	1.20
2002	64,000	1.17	100,000	1.00		2002	13,000	1.40	100,000	1.40
2003	46,000	1.26	100,000	1.00		2003	12,000	1.60	100,000	1.60
2004	28,000	1.34	100,000	1.00		2004	11,000	1.80	100,000	1.80
2005	10,000	1.43	100,000	1.00		2005	10,000	2.00	100,000	2.00
2006	9,500	1.43	100,000	1.07		2006	9,800	2.00	100,000	2.10
2007	9,000	1.43	100,000	1.14		2007	9,600	2.00	100,000	2.20
2008	8,500	1.43	100,000	1.21		2008	9,400	2.00	100,000	2.30
2009	8,000	1.43	100,000	1.28		2009	9,200	2.00	100,000	2.40
2010	7,500	1.43	100,000	1.35		2010	9,000	2.00	100,000	2.50
2011	7,000	1.43	100,000	1.45		2011	8,800	2.00	100,000	2.50
2012	6,500	1.43	100,000	1.55		2012	8,600	2.00	100,000	2.50
2013	6,000	1.43	100,000	1.66		2013	8,400	2.00	100,000	2.50
2014	5,500	1.43	100,000	1.76		2014	8,200	2.00	100,000	2.50
2015	5,000	1.43	100,000	1.86		2015	8,000	2.00	100,000	2.50
2016	5,000	1.43	100,000	1.86		2016	7,800	2.00	100,000	2.50
2017	5,000	1.43	100,000	1.86		2017	7,600	2.00	100,000	2.50
2018	5,000	1.43	100,000	1.86		2018	7,400	2.00	100,000	2.50
2019	5,000	1.43	100,000	1.86		2019	7,200	2.00	100,000	2.50
2020	5,000	1.43	100,000	1.86		2020	7,000	2.00	100,000	2.50
2021	4,600	1.43	100,000	1.86		2021	6,800	2.00	100,000	2.50
2022	4,200	1.43	100,000	1.86		2022	6,600	2.00	100,000	2.50
2023	3,800	1.43	100,000	1.86		2023	6,400	2.00	100,000	2.50
2024	3,400	1.43	100,000	1.86		2024	6,200	2.00	100,000	2.50
2025	3,000	1.43	100,000	1.86		2025	6,000	2.00	100,000	2.50
2026	3,000	1.43	100,000	1.86		2026	6,000	2.00	100,000	2.50
2027	3,000	1.43	100,000	1.86		2027	6,000	2.00	100,000	2.50
2028	3,000	1.43	100,000	1.86		2028	6,000	2.00	100,000	2.50
2029	3,000	1.43	100,000	1.86		2029	6,000	2.00	100,000	2.50
2030	3,000	1.43	100,000	1.86		2030	6,000	2.00	100,000	2.50
2031	3,000	1.43	80,250	1.86		2031	6,000	2.00	100,000	2.50
2032	3,000	1.43	60,500	1.86		2032	6,000	2.00	100,000	2.50
2033	3,000	1.43	40,750	1.86		2033	6,000	2.00	100,000	2.50
2034	3,000	1.43	21,000	1.86		2034	6,000	2.00	100,000	2.50
2035	3,000	1.43	1,250	1.86		2035	6,000	2.00	100,000	2.50

Fuel Prices

Transportation Energy Prices												
AEO'01												
	2000 Dollars per Million Btu						2000 Dollars per Gallon Gasoline Equivalent					
Year	Gasoline	Diesel	LPG	CNG	Electricity	Ethanol	Gasoline	Diesel	LPG	CNG	Electricity	Ethanol
1995	9.23	8.03	12.62	5.77	15.14	18.96	1.15	1.11	1.58	0.72	1.89	2.37
1996	9.89	8.90	12.62	5.41	15.33	17.73	1.24	1.23	1.58	0.68	1.92	2.36
1997	9.59	8.37	12.64	6.17	15.40	16.50	1.20	1.16	1.58	0.77	1.93	2.36
1998	9.37	8.18	12.61	5.69	15.08	15.26	1.17	1.13	1.58	0.71	1.89	2.35
1999	9.56	8.46	12.73	5.56	14.91	14.03	1.20	1.17	1.59	0.70	1.86	2.34
2000	12.20	10.81	11.70	8.04	21.78	17.33	1.52	1.50	1.46	1.00	2.72	1.80
2001	12.15	10.46	11.90	8.26	21.03	16.89	1.52	1.45	1.49	1.03	2.63	1.76
2002	10.98	9.84	12.15	6.11	20.19	16.44	1.37	1.36	1.52	0.76	2.52	1.73
2003	10.93	9.23	12.40	6.39	18.25	16.00	1.37	1.28	1.55	0.80	2.28	1.69
2004	10.92	9.27	12.77	6.56	17.41	15.55	1.36	1.29	1.60	0.82	2.18	1.66
2005	11.02	9.23	13.04	6.64	16.56	15.11	1.38	1.28	1.63	0.83	2.07	1.62
2006	11.24	9.43	13.24	6.69	16.20	14.66	1.41	1.31	1.66	0.84	2.02	1.58
2007	11.22	9.87	13.29	6.73	16.67	14.22	1.40	1.37	1.66	0.84	2.08	1.55
2008	11.25	9.96	13.02	6.81	17.24	13.77	1.41	1.38	1.63	0.85	2.16	1.51
2009	11.29	10.01	13.03	6.85	17.73	13.33	1.41	1.39	1.63	0.86	2.22	1.48
2010	11.27	10.14	13.06	6.89	18.20	12.88	1.41	1.41	1.63	0.86	2.27	1.44
2011	11.30	10.19	13.02	6.95	18.59	12.69	1.41	1.41	1.63	0.87	2.32	1.43
2012	11.31	10.13	13.01	7.01	18.86	12.50	1.41	1.41	1.63	0.88	2.36	1.42
2013	11.29	10.14	13.05	7.06	19.11	12.30	1.41	1.41	1.63	0.88	2.39	1.41
2014	11.28	10.06	13.11	7.09	19.28	12.11	1.41	1.40	1.64	0.89	2.41	1.40
2015	11.28	10.09	12.99	7.13	19.27	11.92	1.41	1.40	1.62	0.89	2.41	1.39
2016	11.27	10.06	13.06	7.16	19.11	11.62	1.41	1.40	1.63	0.89	2.39	1.38
2017	11.26	10.02	13.17	7.19	18.86	11.31	1.41	1.39	1.65	0.90	2.36	1.37
2018	11.27	10.03	13.19	7.22	18.64	11.01	1.41	1.39	1.65	0.90	2.33	1.36
2019	11.28	9.97	13.17	7.24	18.28	10.70	1.41	1.38	1.65	0.90	2.29	1.35
2020	11.28	9.98	13.20	7.28	17.91	10.40	1.41	1.38	1.65	0.91	2.24	1.34
2021	11.42	10.11	13.33	7.31	17.90	10.18	1.43	1.40	1.67	0.91	2.24	1.34
2022	11.57	10.24	13.47	7.34	17.89	9.95	1.45	1.42	1.68	0.92	2.24	1.34
2023	11.71	10.37	13.60	7.37	17.88	9.73	1.46	1.44	1.70	0.92	2.24	1.34
2024	11.86	10.50	13.74	7.40	17.87	9.50	1.48	1.46	1.72	0.92	2.23	1.34
2025	12.00	10.62	13.87	7.43	17.86	9.28	1.50	1.47	1.73	0.93	2.23	1.34
2026	12.16	10.77	14.01	7.46	17.85	9.28	1.52	1.49	1.75	0.93	2.23	1.34
2027	12.32	10.91	14.15	7.49	17.84	9.28	1.54	1.51	1.77	0.94	2.23	1.34
2028	12.48	11.05	14.29	7.52	17.83	9.28	1.56	1.53	1.79	0.94	2.23	1.34
2029	12.64	11.19	14.44	7.55	17.82	9.28	1.58	1.55	1.80	0.94	2.23	1.34
2030	12.80	11.33	14.58	7.58	17.81	9.28	1.60	1.57	1.82	0.95	2.23	1.34
2031	12.96	11.47	14.72	7.61	17.80	9.28	1.62	1.59	1.84	0.95	2.23	1.34
2032	13.12	11.62	14.86	7.64	17.79	9.28	1.64	1.61	1.86	0.95	2.22	1.34
2033	13.28	11.76	15.01	7.67	17.78	9.28	1.66	1.63	1.88	0.96	2.22	1.34
2034	13.44	11.90	15.15	7.70	17.77	9.28	1.68	1.65	1.89	0.96	2.22	1.34
2035	13.60	12.04	15.29	7.73	17.76	9.28	1.70	1.67	1.91	0.97	2.22	1.34
	0.16	0.14	0.14	0.03	-0.01	0.00						
DOE/EIA-0383(97), Annual Energy Outlook 1997, Reference Case Forecast Table A3. Energy Prices by Sector and Source, pgs. 100 and 101.												
Prices Include Federal and State taxes and exclude county and local taxes.												
Ethanol: Programs goals as stated in 1997 Budget.												

Market Data (1)

Class 7 & 8 Vehicle Distribution by Annual VMT and Type 1					
Vehicle Age 2 or Less					
Ref: 1997 VIUS Runs - Stacy Davis ORNL - 5/19/00					
	Vehilces		**Percent**		1
VMT (1000)	Central	Non-Central	Central	Non-Central	
0	0	0	0.00%	0.00%	
5	2095	1126	2.14%	1.15%	
10	5085	3421	5.21%	3.50%	
15	6669	3807	6.83%	3.90%	
20	8260	3799	8.46%	3.89%	
25	5560	3003	5.69%	3.07%	
30	6042	3743	6.19%	3.83%	
35	2646	2094	2.71%	2.14%	
40	2728	2095	2.79%	2.14%	
45	2230	1957	2.28%	2.00%	
50	3432	1853	3.51%	1.90%	
55	1922	1092	1.97%	1.12%	
60	2167	1445	2.22%	1.48%	
65	950	1281	0.97%	1.31%	
70	1280	862	1.31%	0.88%	
75	1166	745	1.19%	0.76%	
80	1156	1160	1.18%	1.19%	
85	606	768	0.62%	0.79%	
90	1084	1148	1.11%	1.18%	
95	474	474	0.49%	0.49%	
100	1643	1582	1.68%	1.62%	
105	320		0.33%	0.00%	
110	456	668	0.47%	0.68%	
115		342	0.00%	0.35%	
120	155	329	0.16%	0.34%	
125	233		0.24%	0.00%	
130			0.00%	0.00%	
135			0.00%	0.00%	
140		517	0.00%	0.53%	
145			0.00%	0.00%	
150			0.00%	0.00%	
155			0.00%	0.00%	
160			0.00%	0.00%	
165			0.00%	0.00%	
170			0.00%	0.00%	
175			0.00%	0.00%	
180			0.00%	0.00%	
185			0.00%	0.00%	
190			0.00%	0.00%	
195			0.00%	0.00%	
200			0.00%	0.00%	
201+			0.00%	0.00%	
Total	58359	39311	59.8%	40.2%	
	97670				
	17.8%				

Class 7 & 8 Vehicle Distribution by Annual VMT and Type 2					
Vehicle Age 2 or Less					
Ref: 1997 VIUS Runs - Stacy Davis ORNL - 5/19/00					
	Vehilces		**Percent**		1
VMT (1000)	Central	Non-Central	Central	Non-Central	
0	0	0	0.00%	0.00%	
5	970	1488	0.78%	1.20%	
10	2156	2814	1.74%	2.27%	
15	2410	4169	1.95%	3.37%	
20	1572	2699	1.27%	2.18%	
25	3204	2357	2.59%	1.90%	
30	2054	2286	1.66%	1.85%	
35	2077	1453	1.68%	1.17%	
40	2057	2285	1.66%	1.85%	
45	2370	1211	1.91%	0.98%	
50	1892	2537	1.53%	2.05%	
55	1812	966	1.46%	0.78%	
60	3026	1940	2.44%	1.57%	
65	2423	1833	1.96%	1.48%	
70	1441	1812	1.16%	1.46%	
75	1648	1261	1.33%	1.02%	
80	1732	3003	1.40%	2.43%	
85	1306	1311	1.06%	1.06%	
90	1734	2642	1.40%	2.13%	
95	1450	2314	1.17%	1.87%	
100	3201	7882	2.59%	6.37%	
105	924	2386	0.75%	1.93%	
110	1126	3835	0.91%	3.10%	
115	1387	1902	1.12%	1.54%	
120	1935	5453	1.56%	4.41%	
125	941	2464	0.76%	1.99%	
130	657	2841	0.53%	2.30%	
135	219	1269	0.18%	1.03%	
140	701	1342	0.57%	1.08%	
145	185	551	0.15%	0.45%	
150	585	1353	0.47%	1.09%	
155	575	349	0.46%	0.28%	
160	550	506	0.44%	0.41%	
165			0.00%	0.00%	
170			0.00%	0.00%	
175			0.00%	0.00%	
180		316	0.00%	0.26%	
185			0.00%	0.00%	
190			0.00%	0.00%	
195			0.00%	0.00%	
200			0.00%	0.00%	
201+	461	162	0.37%	0.13%	
Total	50781	72992	41.0%	59.0%	
	123773				
	22.6%				

Market Data (2)

VMT (1000)						VMT (1000)				
0	0.0%	0.0%	0.00	0.00		0	0.0%	0.0%	0.00	0.00
5	15.1%	13.5%	0.76	0.67		5	17.5%	17.6%	0.88	0.88
10	36.7%	41.0%	3.67	4.10		10	38.9%	33.2%	3.89	3.32
15	48.2%	45.6%	7.22	6.84		15	43.5%	49.2%	6.53	7.38
	13849	8354	11.65	11.60			5536	8471	11.30	11.58
20	36.7%	30.1%	7.34	6.01		20	17.6%	30.7%	3.53	6.14
25	24.7%	23.8%	6.18	5.94		25	36.0%	26.8%	8.99	6.70
30	26.8%	29.6%	8.05	8.88		30	23.1%	26.0%	6.92	7.80
35	11.8%	16.6%	4.11	5.80		35	23.3%	16.5%	8.16	5.78
	22508	12639	25.68	26.63			8907	8795	27.60	26.42
40	26.5%	29.9%	10.58	11.98		40	25.3%	32.6%	10.12	13.06
45	21.6%	28.0%	9.73	12.59		45	29.1%	17.3%	13.12	7.79
50	33.3%	26.5%	16.64	13.24		50	23.3%	36.2%	11.63	18.12
55	18.6%	15.6%	10.25	8.58		55	22.3%	13.8%	12.26	7.59
	10312	6997	47.21	46.39			8131	6999	47.13	46.56
60	39.0%	33.3%	23.37	20.01		60	35.4%	28.3%	21.26	17.00
65	17.1%	29.6%	11.10	19.22		65	28.4%	26.8%	18.45	17.40
70	23.0%	19.9%	16.11	13.93		70	16.9%	26.5%	11.81	18.53
75	21.0%	17.2%	15.72	12.90		75	19.3%	18.4%	14.48	13.81
	5563	4333	66.30	66.05			8538	6846	66.00	66.75
80	34.8%	32.7%	27.86	26.14		80	27.8%	32.4%	22.27	25.92
85	18.3%	21.6%	15.52	18.39		85	21.0%	14.1%	17.84	12.02
90	32.7%	32.3%	29.39	29.10		90	27.9%	28.5%	25.08	25.65
95	14.3%	13.4%	13.56	12.68		95	23.3%	25.0%	22.14	23.71
	3320	3550	86.32	86.32			6222	9270	87.33	87.30
100	67.9%	61.0%	67.92	61.03		100	48.2%	49.2%	48.22	49.25
105	13.2%	0.0%	13.89	0.00		105	13.9%	14.9%	14.62	15.65
110	18.9%	25.8%	20.74	28.35		110	17.0%	24.0%	18.66	26.36
115	0.0%	13.2%	0.00	15.17		115	20.9%	11.9%	24.03	13.67
	2419	2592	102.55	104.56			6638	16005	105.53	104.92
120	39.9%	100.0%	47.94	120.00		120	51.6%	45.3%	61.89	54.41
125	60.1%	0.0%	75.06	0.00		125	25.1%	20.5%	31.35	25.61
130	0.0%	0.0%	0.00	0.00		130	17.5%	23.6%	22.76	30.71
135	0.0%	0.0%	0.00	0.00		135	5.8%	10.6%	7.88	14.24
	388	329	123.00	120.00			3752	12027	123.88	124.97

Market Data (3)

140	#DIV/0!	100.0%	#DIV/0!	140.00		140	34.3%	37.3%	47.97	52.26
145	#DIV/0!	0.0%	#DIV/0!	0.00		145	9.0%	15.3%	13.11	22.22
150	#DIV/0!	0.0%	#DIV/0!	0.00		150	28.6%	37.6%	42.89	56.45
155	#DIV/0!	0.0%	#DIV/0!	0.00		155	28.1%	9.7%	43.56	15.05
	0	517	#DIV/0!	140.00			2046	3595	147.53	145.99
160	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		160	100.0%	100.0%	160.00	160.00
165	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		165	0.0%	0.0%	0.00	0.00
170	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		170	0.0%	0.0%	0.00	0.00
175	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		175	0.0%	0.0%	0.00	0.00
	0	0	#DIV/0!	167.50			550	506	160.00	160.00
180	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		180	#DIV/0!	100.0%	#DIV/0!	180.00
185	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		185	#DIV/0!	0.0%	#DIV/0!	0.00
190	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		190	#DIV/0!	0.0%	#DIV/0!	0.00
195	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		195	#DIV/0!	0.0%	#DIV/0!	0.00
	0	0	#DIV/0!	187.50			0	316	#DIV/0!	180.00
200	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		200	0.0%	0.0%	0.00	0.00
225	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		225	100.0%	100.0%	225.00	225.00
	0	0	#DIV/0!	#DIV/0!			461	162	225.00	225.00
Total						Total				
TYPE 1						**TYPE 2**				
VMT	Central	Non-Central	Central	Non-Central		VMT	Central	Non-Central	Central	Non-Central
0-19.9	11651	11605	14.18%	8.55%	#####	0-19.9	11301	11582	4.47%	6.84%
20-39.9	25683	26635	23.04%	12.94%	#####	20-39.9	27602	26417	7.20%	7.11%
40-59.9	47205	46388	10.56%	7.16%	#####	40-59.9	47127	46560	6.57%	5.65%
60-79.9	66299	66047	5.70%	4.44%	#####	60-79.9	66002	66748	6.90%	5.53%
80-99.9	86319	86318	3.40%	3.63%	7.03%	80-99.9	87332	87302	5.03%	7.49%
100-119.9	102547	104556	2.48%	2.65%	5.13%	100-119.9	105527	104924	5.36%	12.93%
120-139.9	123003	120000	0.40%	0.34%	0.73%	120-139.9	123881	124969	3.03%	9.72%
140-159.9	147500	140000	0.00%	0.53%	0.53%	140-159.9	147527	145986	1.65%	2.90%
160-179.9	167500	167500	0.00%	0.00%	0.00%	160-179.9	160000	160000	0.44%	0.41%
180-199.9	187500	187500	0.00%	0.00%	0.00%	180-199.9	187500	180000	0.00%	0.26%
200+	212500	212500	0.00%	0.00%	0.00%	200+	225000	225000	0.37%	0.13%
					#####					

Market Data (4)

Class 7 & 8 Vehicle Distribution by Annual VMT and Type 3
Vehicle Age 2 or Less
Ref: 1997 VIUS Runs - Stacy Davis ORNL - 5/19/00

	Vehilces		Percent	
VMT (1000)	Central	Non-Central	Central	Non-Central
0	0	0	0.00%	0.00%
5	992	2415	0.30%	0.74%
10	1668	2540	0.51%	0.78%
15	2253	4249	0.69%	1.30%
20	5372	3213	1.65%	0.98%
25	3705	4804	1.13%	1.47%
30	4236	4181	1.30%	1.28%
35	4565	2671	1.40%	0.82%
40	5572	3484	1.71%	1.07%
45	3993	3862	1.22%	1.18%
50	4782	9041	1.46%	2.77%
55	3047	3080	0.93%	0.94%
60	4099	4511	1.26%	1.38%
65	3120	2385	0.96%	0.73%
70	8200	3590	2.51%	1.10%
75	2998	2473	0.92%	0.76%
80	5837	5536	1.79%	1.70%
85	3746	6443	1.15%	1.97%
90	4599	7105	1.41%	2.18%
95	4050	4488	1.24%	1.37%
100	9632	12363	2.95%	3.79%
105	5394	3439	1.65%	1.05%
110	4371	8494	1.34%	2.60%
115	2009	5211	0.62%	1.60%
120	12702	17135	3.89%	5.25%
125	4001	10150	1.23%	3.11%
130	4358	13665	1.33%	4.18%
135	2412	3467	0.74%	1.06%
140	1899	4071	0.58%	1.25%
145	1205	1632	0.37%	0.50%
150	1094	9778	0.34%	2.99%
155	906	1378	0.28%	0.42%
160	2027	2619	0.62%	0.80%
165	678	1325	0.21%	0.41%
170	831	2235	0.25%	0.68%
175	689	1478	0.21%	0.45%
180	949	2309	0.29%	0.71%
185	516	601	0.16%	0.18%
190		958	0.00%	0.29%
195	1340		0.41%	0.00%
200	1639	1966	0.50%	0.60%
201+	1560	5171	0.48%	1.58%
Total	137046	189516	42.0%	58.0%
	326562			
	59.6%			

Class 3-6 Vehicle Distribution by Annual VMT and Primary Refueling
Vehicle Age 2 or Less
Ref: 1997 VIUS Runs - Stacy Davis ORNL - 5/19/00

	Vehilces		Percent	
VMT (1000)	Central	Non-Central	Central	Non-Central
0	11054	18352	2.96%	4.92%
5	16924	40557	4.53%	10.87%
10	19827	36129	5.31%	9.68%
15	20225	30780	5.42%	8.25%
20	19598	19704	5.25%	5.28%
25	17261	29072	4.62%	7.79%
30	9028	8932	2.42%	2.39%
35	7313	11853	1.96%	3.18%
40	5152	8780	1.38%	2.35%
45	3318	7572	0.89%	2.03%
50	1790	2504	0.48%	0.67%
55	2611	2031	0.70%	0.54%
60	2827		0.76%	0.00%
65	2390	1118	0.64%	0.30%
70	904		0.24%	0.00%
75	3241	2078	0.87%	0.56%
80			0.00%	0.00%
85	462		0.12%	0.00%
90			0.00%	0.00%
95	849	903	0.23%	0.24%
100	3841	2963	1.03%	0.79%
100+	980	300	0.26%	0.08%
Total	149595	223628	40.08%	59.92%
	373223			

Market Data (5)

VMT (1000)						VMT (1000)				
0	0.0%	0.0%	0.00	0.00		0	16.2%	14.6%	0.00	0.00
5	20.2%	26.2%	1.01	1.31		5	24.9%	32.2%	1.24	1.61
10	34.0%	27.6%	3.40	2.76		10	29.1%	28.7%	2.91	2.87
15	45.9%	46.2%	6.88	6.92		15	29.7%	24.5%	4.46	3.67
	4913	9204	11.28	11.00			68030	125818	8.62	8.15
20	30.0%	21.6%	6.01	4.32		20	36.8%	28.3%	7.37	5.67
25	20.7%	32.3%	5.18	8.08		25	32.4%	41.8%	8.11	10.45
30	23.7%	28.1%	7.11	8.44		30	17.0%	12.8%	5.09	3.85
35	25.5%	18.0%	8.94	6.29		35	13.7%	17.0%	4.81	5.96
	17878	14869	27.24	27.12			53200	69561	25.38	25.93
40	32.0%	17.9%	12.81	7.16		40	40.0%	42.0%	16.01	16.81
45	23.0%	19.8%	10.33	8.93		45	25.8%	36.3%	11.60	16.31
50	27.5%	46.4%	13.75	23.22		50	13.9%	12.0%	6.95	5.99
55	17.5%	15.8%	9.63	8.70		55	20.3%	9.7%	11.16	5.35
	17394	19467	46.52	48.01			12871	20887	45.72	44.47
60	22.3%	34.8%	13.35	20.89		60	30.2%	0.0%	18.12	0.00
65	16.9%	18.4%	11.01	11.96		65	25.5%	35.0%	16.59	22.74
70	44.5%	27.7%	31.17	19.39		70	9.7%	0.0%	6.76	0.00
75	16.3%	19.1%	12.21	14.31		75	34.6%	65.0%	25.96	48.76
	18417	12959	67.74	66.55			9362	3196	67.43	71.50
80	32.0%	23.5%	25.61	18.79		80	0.0%	0.0%	0.00	0.00
85	20.5%	27.3%	17.46	23.23		85	35.2%	0.0%	29.95	0.00
90	25.2%	30.1%	22.70	27.13		90	0.0%	0.0%	0.00	0.00
95	22.2%	19.0%	21.10	18.09		95	64.8%	100.0%	61.52	95.00
	18232	23572	86.88	87.24			1311	903	91.48	95.00
100	45.0%	41.9%	45.00	41.90		100	79.7%	90.8%	79.67	90.81
105	25.2%	11.7%	26.46	12.24		105	20.3%	9.2%	21.34	9.65
110	20.4%	28.8%	22.46	31.67		110	0.0%	0.0%	0.00	0.00
115	9.4%	17.7%	10.79	20.31		115	0.0%	0.0%	0.00	0.00
	21406	29507	104.71	106.11			4821	3263	101.02	100.46
120	54.1%	38.6%	64.94	46.29		120	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
125	17.0%	22.9%	21.31	28.56		125	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
130	18.6%	30.8%	24.14	39.99		130	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
135	10.3%	7.8%	13.87	10.54		135	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
	23473	44417	124.25	125.39			0	0	127.50	127.50

Market Data (6)

140	37.2%	24.1%	52.09	33.81		140	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
145	23.6%	9.7%	34.23	14.04		145	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
150	21.4%	58.0%	32.15	87.00		150	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
155	17.8%	8.2%	27.51	12.67		155	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	5104	16859	145.99	147.51			0	0	147.50	147.50		
160	48.0%	34.2%	76.76	54.73		160	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
165	16.0%	17.3%	26.48	28.55		165	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
170	19.7%	29.2%	33.44	49.62		170	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
175	16.3%	19.3%	28.54	33.78		175	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	4225	7657	165.22	166.68			0	0	167.50	167.50		
180	33.8%	59.7%	60.90	107.45		180	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
185	18.4%	15.5%	34.03	28.74		185	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
190	0.0%	24.8%	0.00	47.06		190	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
195	47.8%	0.0%	93.16	0.00		195	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	2805	3868	188.09	183.25			0	0	187.50	187.50		
200	51.2%	27.5%	102.47	55.09		200	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
225	48.8%	72.5%	109.72	163.02		225	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!		
	3199	7137	212.19	218.11			0	0	212.50	212.50		
Total						Total						
TYPE 3						**CLS 3-6**						
VMT	Central	Non-Central	Central	Non-Central		VMT	Central	Non-Central	Central	Non-Central		
0-19.9	11283	10996	1.50%	2.82%	4.32%	0-19.9	8618	8153	18.23%	33.71%	51.94%	
20-39.9	27236	27122	5.47%	4.55%	10.03%	20-39.9	25381	25930	14.25%	18.64%	32.89%	
40-59.9	46525	48009	5.33%	5.96%	11.29%	40-59.9	45723	44470	3.45%	5.60%	9.04%	
60-79.9	67741	66553	5.64%	3.97%	9.61%	60-79.9	67435	71502	2.51%	0.86%	3.36%	
80-99.9	86882	87237	5.58%	7.22%	12.80%	80-99.9	91476	95000	0.35%	0.24%	0.59%	
100-119.9	104710	106110	6.55%	9.04%	15.59%	100-119.9	101016	100460	1.29%	0.87%	2.17%	
120-139.9	124250	125390	7.19%	13.60%	20.79%	120-139.9	127500	127500	0.00%	0.00%	0.00%	
140-159.9	145986	147510	1.56%	5.16%	6.73%	140-159.9	147500	147500	0.00%	0.00%	0.00%	
160-179.9	165215	166680	1.29%	2.34%	3.64%	160-179.9	167500	167500	0.00%	0.00%	0.00%	
180-199.9	188086	183254	0.86%	1.18%	2.04%	180-199.9	187500	187500	0.00%	0.00%	0.00%	
200+	212191	218113	0.98%	2.19%	3.17%	200+	212500	212500	0.00%	0.00%	0.00%	
					100.00%						100.00%	

Type 1 (1)

TYPE 1:	Multi-stop or Step Van; Beverage; Utility; Winch or Crane; Wrecker; Pole, Logging,											
	Pipe; Service; Garbage; Dump; Cement Mixer; Yard Tractor and Other											
	Please enter one of the following alternative fuel types: LPG, CNG, Electricity, Ethanol, Gasoline											
	Fuel Type	**Ethanol**										
	Discount Rate	**10.0%**										
	Annual VMT	212500										
	Fuel Efficiency Escalation Factor:	1.00										
	Baseline	ADV. Diesel	ADV. Diesel	Ethanol	Ethanol	Ethanol	**ANNUAL DOLLAR SAVINGS**		**NPV of Advanced Diesel Savings**			
	Fuel Efficiency	Efficiency	Adjusted	Efficiency	Adjusted	Fuel	**OF TECHNOLOGY**		Payback Periods (years)			
Year	MPG	Improvement	MPG	Improvement	MPG	Cost	ADV. Diesel	Alt. Fuel	1	2	3	4
1995	4.50	0.01	0.05	1.00	4.50	2.37	-5206692.09	-59323.82	-4733356.45	-4915876.92	-4957087.20	-4973494.56
1996	4.52	0.21	0.94	1.00	4.52	2.36	-220849.77	-52889.05	-200772.52	-246103.83	-264151.92	-270541.73
1997	6.58	0.41	2.67	1.00	6.58	2.36	-54850.89	-38725.13	-49864.44	-69717.34	-76746.14	-76746.14
1998	6.58	0.60	3.97	1.00	6.58	2.35	-24022.01	-39253.23	-21838.19	-29569.87	-29569.87	-27035.85
1999	6.58	0.80	5.28	1.00	6.58	2.34	-9355.33	-37676.11	-8504.84	-8504.84	-5717.42	-1300.05
2000	6.58	1.00	6.58	1.00	6.58	1.80	0.00	-9727.36	0.00	3066.16	7925.27	13713.81
2001	6.58	1.09	7.15	1.00	6.58	1.76	3710.05	-10117.88	3372.78	8717.80	15085.19	22340.79
2002	6.58	1.17	7.71	1.00	6.58	1.73	6467.47	-11736.40	5879.52	12883.66	20864.82	29353.17
2003	6.58	1.26	8.28	1.00	6.58	1.69	8475.01	-13318.99	7704.55	16483.83	25821.01	34494.78
2004	6.58	1.34	8.84	1.00	6.58	1.66	10622.93	-11976.72	9657.21	19928.10	29469.26	38548.62
2005	6.58	1.43	9.41	1.00	6.58	1.62	12427.79	-10988.01	11297.99	21793.26	31780.56	40942.51
2006	6.58	1.43	9.41	1.07	7.04	1.58	12699.27	-5575.96	11544.79	22530.82	32608.97	41817.34
2007	6.58	1.43	9.41	1.14	7.50	1.55	13293.10	354.29	12084.63	23170.60	33299.80	42627.51
2008	6.58	1.43	9.41	1.21	7.96	1.51	13414.02	4254.21	12194.56	23336.68	33597.17	42972.05
2009	6.58	1.43	9.41	1.28	8.42	1.48	13481.97	7595.40	12256.33	23542.87	33855.24	43175.40
2010	6.58	1.43	9.41	1.35	8.88	1.44	13656.71	10968.66	12415.19	23758.80	34010.97	43336.35
2011	6.58	1.43	9.41	1.45	9.55	1.43	13725.77	13840.65	12477.97	23755.36	34013.28	43272.05
2012	6.58	1.43	9.41	1.55	10.23	1.42	13645.64	15869.61	12405.13	23688.84	33873.48	43159.03
2013	6.58	1.43	9.41	1.66	10.90	1.41	13653.29	17907.72	12412.08	23615.19	33829.29	43083.43
2014	6.58	1.43	9.41	1.76	11.57	1.40	13555.76	19362.47	12323.41	23558.93	33738.48	42959.39
2015	6.58	1.43	9.41	1.86	12.24	1.39	13594.98	21076.89	12359.07	23556.58	33699.58	42925.52
2016	6.58	1.43	9.41	1.86	12.24	1.38	13548.98	21097.56	12317.26	23474.56	33623.10	42799.37
2017	6.58	1.43	9.41	1.86	12.24	1.37	13500.33	21109.41	12273.03	23436.43	33530.33	42714.71
2018	6.58	1.43	9.41	1.86	12.24	1.36	13507.71	21307.57	12279.74	23383.03	33485.84	42788.13
2019	6.58	1.43	9.41	1.86	12.24	1.35	13434.98	21239.32	12213.62	23326.72	33559.23	42979.43
2020	6.58	1.43	9.41	1.86	12.24	1.34	13446.85	21452.43	12224.41	23480.18	33842.40	43380.50
2021	6.58	1.43	9.41	1.86	12.24	1.34	13619.48	22026.52	12381.35	23779.79	34271.70	43927.72
2022	6.58	1.43	9.41	1.86	12.24	1.34	13792.11	22600.62	12538.28	24079.39	34701.01	44474.93
2023	6.58	1.43	9.41	1.86	12.24	1.34	13964.74	23174.71	12695.22	24379.00	35130.31	45034.56
2024	6.58	1.43	9.41	1.86	12.24	1.34	14137.37	23748.81	12852.16	24678.60	35573.27	45607.83
2025	6.58	1.43	9.41	1.86	12.24	1.34	14310.00	24322.90	13009.09	24993.23	36031.24	46196.12
2026	6.58	1.43	9.41	1.86	12.24	1.34	14500.80	24957.43	13182.55	25324.37	36505.73	46800.93
2027	6.58	1.43	9.41	1.86	12.24	1.34	14691.60	25591.95	13356.00	25655.51	36980.23	47405.74
2028	6.58	1.43	9.41	1.86	12.24	1.34	14882.40	26226.47	13529.46	25986.65	37454.72	48010.55
2029	6.58	1.43	9.41	1.86	12.24	1.34	15073.20	26860.99	13702.91	26317.79	37929.21	48615.37
2030	6.58	1.43	9.41	1.86	12.24	1.34	15264.00	27495.51	13876.37	26648.93	38403.70	49220.18
2031	6.58	1.43	9.41	1.86	12.24	1.34	15454.80	28130.03				
2032	6.58	1.43	9.41	1.86	12.24	1.34	15645.60	28764.55				

Type 1 (2)

NPV of Alternative Fuel Savings				Cost Effectiveness Factor Adv. Diesel					Cost Effectiveness Factor Alt. Fuels				
Payback Periods (years)				Payback Periods (years)				Tech	Payback Periods (years)				
1	2	3	4	1	2	3	4	Cost	1	2	3	4	
-53930.74	-97640.70	-126735.46	-153545.95	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.00
-48080.95	-80085.19	-109576.72	-135310.01	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-35204.67	-67645.35	-95951.97	-102595.89	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-35684.75	-66822.03	-74130.34	-81040.99	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-34251.01	-42290.15	-49891.87	-57907.99	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-8843.06	-17204.94	-26022.68	-35119.72	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-9198.07	-18897.58	-28904.33	-37084.59	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10669.46	-21676.89	-30675.17	-38180.13	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-12108.17	-22006.29	-30261.74	-34070.20	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10887.93	-19968.93	-24158.23	-23916.24	0.00	0.00	-0.05	-0.38	100000	0.00	0.00	0.00	0.00	100.0
-9989.10	-14597.33	-14331.15	-11425.46	-0.13	-1.18	-2.18	-3.09	100000	0.00	0.00	0.00	0.00	98.6
-5069.05	-4776.25	-1580.00	3607.76	-0.22	-1.37	-2.43	-3.40	100000	0.00	0.00	0.00	0.00	97.6
322.08	3837.96	9544.49	17036.24	-0.34	-1.57	-2.70	-3.74	100000	0.00	0.00	0.00	0.00	95.9
3867.46	10144.65	18385.57	27838.92	-0.43	-1.75	-2.95	-4.06	100000	0.00	0.00	0.00	0.00	94.6
6904.91	15969.92	26368.60	37207.76	-0.53	-1.94	-3.23	-4.40	100000	0.00	0.00	0.00	0.00	93.0
9971.51	21410.07	33333.14	45564.35	-0.66	-2.17	-3.53	-4.78	100000	0.00	0.00	0.00	0.00	90.7
12582.41	25697.79	39152.13	52376.96	-0.78	-2.39	-3.86	-5.18	100000	0.00	0.00	0.00	0.00	88.1
14426.91	29226.69	43774.00	58169.80	-0.91	-2.64	-4.21	-5.64	100000	0.00	0.00	0.00	0.00	85.2
16279.75	32281.79	48117.17	62527.09	-1.07	-2.94	-4.64	-6.18	100000	0.00	0.00	0.00	0.00	80.9
17602.25	35021.16	50872.08	65290.08	-1.24	-3.28	-5.13	-6.81	100000	0.00	0.00	0.00	0.00	75.4
19160.81	36596.81	52456.62	67009.97	-1.47	-3.71	-5.74	-7.59	100000	0.00	0.00	0.00	0.00	66.4
19179.60	36625.39	52634.08	67140.82	-1.46	-3.69	-5.72	-7.56	100000	0.00	0.00	0.00	0.00	66.8
19190.37	36799.93	52757.34	67409.64	-1.45	-3.69	-5.71	-7.54	100000	0.00	0.00	0.00	0.00	67.2
19370.52	36923.67	53041.20	68085.61	-1.46	-3.68	-5.70	-7.56	100000	0.00	0.00	0.00	0.00	67.1
19308.47	37037.75	53586.60	69023.13	-1.44	-3.67	-5.71	-7.60	100000	0.00	0.00	0.00	0.00	67.7
19502.21	37705.94	54686.12	70514.76	-1.44	-3.70	-5.77	-7.68	100000	0.00	0.00	0.00	0.00	67.6
20024.11	38702.31	56113.81	72334.57	-1.69	-4.17	-6.45	-8.55	100000	0.00	0.00	0.00	0.00	55.7
20546.02	39698.67	57541.50	74154.38	-1.99	-4.73	-7.26	-9.59	100000	0.00	0.00	0.00	0.00	37.2
21067.92	40695.04	58969.19	76015.45	-2.34	-5.42	-8.24	-10.85	100000	0.00	0.00	0.00	0.00	6.1
21589.83	41691.40	60442.28	77921.93	-2.78	-6.26	-9.46	-12.41	100000	0.00	0.00	0.00	0.00	-51.2
22111.73	42737.70	61965.31	79878.34	-3.34	-7.33	-11.01	-14.40	100000	0.00	0.00	0.00	0.00	-171.2
22688.57	43838.94	63543.27	81889.69	-3.39	-7.44	-11.17	-14.60	100000	0.00	0.00	0.00	0.00	-187.9
23265.41	44940.17	65121.23	83901.03	-3.45	-7.55	-11.33	-14.80	100000	0.00	0.00	0.00	0.00	-205.6
23842.24	46041.41	66699.19	85912.38	-3.51	-7.66	-11.48	-15.00	100000	0.00	0.00	0.00	0.00	-224.4
24419.08	47142.64	68277.15	87923.73	-3.57	-7.77	-11.64	-15.21	100000	0.00	0.00	0.00	0.00	-244.3
24995.92	48243.88	69855.11	89935.07	-3.63	-7.88	-11.80	-15.41	100000	0.00	0.00	0.00	0.00	-265.4

Type 1 (3)

Tech. Adoption Factor Adv. Diesel								Tech. Adoption Factor Alt. Fuels						
Payback Periods (years)								Payback Periods (years)						
1		2		3		4		1		2		3		4
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	99.5	99.5	95.4	95.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
98.6	77.5	77.5	21.7	21.7	-110.7	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
97.6	70.6	70.6	-3.9	0.0	-190.2	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
95.9	61.7	61.7	-38.8	0.0	-309.5	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
94.6	52.7	52.7	-81.6	0.0	-467.2	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
93.0	40.2	40.2	-143.3	0.0	-702.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
90.7	22.6	22.6	-232.9	0.0	-1078.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
88.1	0.5	0.5	-364.2	0.0	-1669.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
85.2	-30.8	0.0	-564.4	0.0	-2704.2	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
80.9	-78.4	0.0	-923.6	0.0	-4722.7	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
75.4	-156.7	0.0	-1587.4	0.0	-8966.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
66.4	-299.1	0.0	-3000.4	0.0	-19576.5	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
66.8	-292.4	0.0	-2953.2	0.0	-19086.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67.2	-289.4	0.0	-2896.9	0.0	-18763.7	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67.1	-285.1	0.0	-2870.2	0.0	-19042.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67.7	-280.7	0.0	-2914.3	0.0	-19789.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
67.6	-292.9	0.0	-3090.5	0.0	-21452.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
55.7	-536.8	0.0	-6219.4	0.0	-51531.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
37.2	-1026.6	0.0	-14143.1	0.0	-145961.9	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
6.1	-2138.7	0.0	-37968.5	0.0	-515849.7	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-5113.9	0.0	-128599.3	0.0	-2462305.0	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-15160.2	0.0	-604899.5	0.0	-17917471.4	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-16942.3	0.0	-708572.8	0.0	-21919592.6	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-18932.3	0.0	-830011.3	0.0	-26815638.8	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-21154.6	0.0	-972259.3	0.0	-32805279.6	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-23636.3	0.0	-1138882.6	0.0	-40132783.3	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-26407.5	0.0	-1334058.1	0.0	-49096978.8	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Type 1 (4)

Market Penetration Advanced Diesel						Market Penetration Alternative Fuels					
16.4%	**61.7%**	**15.5%**	**6.4%**			**16.4%**	**61.7%**	**15.5%**	**6.4%**		
Payback Periods (years)				Final	Final	Payback Periods (years)				Final	Final
1	2	3	4	Step 1	Step 2	1	2	3	4	Step 1	Step 2
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	1.1%	2.2%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.3%	12.0%	78.2%	100.0%	26.1%	26.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.6%	18.0%	100.0%	100.0%	33.3%	33.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.0%	27.4%	100.0%	100.0%	39.1%	39.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.5%	38.4%	100.0%	100.0%	46.0%	46.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.0%	54.8%	100.0%	100.0%	56.2%	56.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.9%	77.2%	100.0%	100.0%	70.2%	70.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.1%	99.6%	100.0%	100.0%	84.2%	84.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6.7%	100.0%	100.0%	100.0%	84.7%	84.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
9.5%	100.0%	100.0%	100.0%	85.2%	85.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
13.7%	100.0%	100.0%	100.0%	85.8%	85.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
22.2%	100.0%	100.0%	100.0%	87.2%	87.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.8%	100.0%	100.0%	100.0%	87.2%	87.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.4%	100.0%	100.0%	100.0%	87.1%	87.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.5%	100.0%	100.0%	100.0%	87.1%	87.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
20.9%	100.0%	100.0%	100.0%	87.0%	87.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.0%	100.0%	100.0%	100.0%	87.0%	87.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
34.6%	100.0%	100.0%	100.0%	89.3%	89.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
58.8%	100.0%	100.0%	100.0%	93.2%	93.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
94.7%	100.0%	100.0%	100.0%	99.1%	99.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.6%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Type 1 (5)

Class 7-8 Type 1 Market Penetration by Average Annual VMT - Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.6%	3.1%	6.7%	11.8%	17.3%	26.1%	0.1%
0.0%	0.0%	0.0%	0.3%	0.7%	2.1%	4.2%	9.4%	15.7%	22.5%	33.3%	0.1%
0.0%	0.0%	0.1%	0.4%	1.6%	2.8%	5.9%	13.1%	20.1%	29.2%	39.1%	0.2%
0.0%	0.0%	0.1%	0.5%	1.9%	3.6%	7.9%	16.5%	24.9%	34.6%	46.0%	0.2%
0.0%	0.0%	0.1%	0.6%	2.4%	4.7%	10.6%	20.5%	31.2%	39.9%	56.2%	0.3%
0.0%	0.0%	0.3%	0.7%	3.1%	6.4%	14.3%	26.0%	36.7%	48.3%	70.2%	0.4%
0.0%	0.0%	0.3%	1.6%	4.1%	8.7%	18.0%	32.6%	42.9%	59.2%	84.2%	0.6%
0.0%	0.0%	0.4%	2.0%	5.5%	12.0%	22.6%	37.7%	52.3%	73.2%	84.7%	0.7%
0.0%	0.0%	0.5%	2.6%	7.9%	16.1%	29.3%	45.4%	66.0%	84.5%	85.2%	1.0%
0.0%	0.0%	0.6%	3.6%	11.5%	21.2%	36.1%	58.0%	83.2%	84.9%	85.8%	1.3%
0.0%	0.1%	1.5%	5.4%	16.6%	29.0%	45.2%	76.7%	84.8%	85.6%	87.2%	1.9%
0.0%	0.1%	1.5%	5.3%	16.5%	28.7%	44.7%	76.0%	84.8%	85.5%	87.2%	1.9%
0.0%	0.1%	1.5%	5.3%	16.2%	28.5%	44.5%	75.7%	84.8%	85.5%	87.1%	1.9%
0.0%	0.1%	1.5%	5.3%	16.1%	28.4%	44.3%	75.2%	84.8%	85.5%	87.1%	1.9%
0.0%	0.1%	1.5%	5.3%	16.2%	28.4%	44.0%	74.7%	84.7%	85.5%	87.0%	1.9%
0.0%	0.1%	1.6%	5.5%	16.5%	29.1%	44.8%	76.0%	84.7%	85.5%	87.0%	2.0%
0.0%	0.1%	2.1%	8.5%	22.6%	36.6%	59.1%	84.6%	85.3%	86.6%	89.3%	2.6%
0.0%	0.1%	3.1%	13.3%	31.7%	47.0%	79.7%	85.2%	86.4%	88.7%	93.2%	3.7%
0.0%	0.4%	4.9%	19.3%	40.3%	65.5%	84.8%	86.2%	88.7%	92.7%	99.1%	5.0%
0.0%	0.5%	8.5%	29.0%	56.5%	84.5%	85.6%	88.6%	93.1%	99.0%	99.9%	7.0%
0.0%	1.4%	15.2%	40.0%	83.6%	85.2%	87.5%	93.6%	99.9%	99.9%	#####	9.5%
0.0%	1.5%	15.8%	41.3%	84.4%	85.3%	87.8%	94.3%	99.9%	99.9%	#####	9.7%
0.0%	1.5%	16.3%	42.7%	84.5%	85.4%	88.1%	94.9%	99.9%	100.0%	#####	9.8%
0.0%	1.6%	17.1%	44.1%	84.5%	85.6%	88.4%	95.6%	99.9%	100.0%	#####	10.0%
0.0%	1.6%	17.8%	45.6%	84.6%	85.7%	88.8%	96.3%	99.9%	100.0%	#####	10.2%
0.0%	1.7%	18.5%	47.2%	84.6%	85.8%	89.1%	97.0%	99.9%	100.0%	#####	10.4%

Type 1 (6)

Class 7-8 Type 1 Market Penetration by Average Annual VMT - Centrally Refueled Alternative Fuels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Type 1 (7)

Class 7-8 Type 1 Market Penetration by Average Annual VMT - Non-Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.8%	2.8%	5.3%	11.8%	17.3%	26.1%	0.1%
0.0%	0.0%	0.0%	0.3%	0.7%	2.3%	3.8%	7.5%	15.7%	22.5%	33.3%	0.2%
0.0%	0.0%	0.1%	0.4%	1.6%	3.0%	5.3%	10.5%	20.1%	29.2%	39.1%	0.2%
0.0%	0.0%	0.1%	0.5%	1.9%	3.9%	7.0%	13.9%	24.9%	34.6%	46.0%	0.3%
0.0%	0.0%	0.1%	0.6%	2.4%	5.1%	9.5%	17.4%	31.2%	39.9%	56.2%	0.4%
0.0%	0.0%	0.1%	0.7%	3.1%	7.0%	12.9%	21.8%	36.7%	48.3%	70.2%	0.5%
0.0%	0.0%	0.3%	1.6%	4.1%	9.5%	16.7%	27.5%	42.9%	59.2%	84.2%	0.7%
0.0%	0.0%	0.4%	2.0%	5.5%	13.0%	20.8%	34.0%	52.3%	73.2%	84.7%	0.9%
0.0%	0.0%	0.5%	2.6%	7.9%	17.3%	27.0%	39.8%	66.0%	84.5%	85.2%	1.2%
0.0%	0.0%	0.6%	3.6%	11.5%	22.6%	34.5%	49.7%	83.2%	84.9%	85.8%	1.6%
0.0%	0.1%	1.5%	5.3%	16.6%	30.9%	42.4%	66.1%	84.8%	85.6%	87.2%	2.3%
0.0%	0.1%	1.4%	5.2%	16.5%	30.6%	42.0%	65.4%	84.8%	85.5%	87.2%	2.2%
0.0%	0.1%	1.4%	5.2%	16.2%	30.4%	41.8%	65.0%	84.8%	85.5%	87.1%	2.2%
0.0%	0.1%	1.4%	5.2%	16.1%	30.2%	41.6%	64.6%	84.8%	85.5%	87.1%	2.2%
0.0%	0.1%	1.4%	5.2%	16.2%	30.2%	41.3%	64.1%	84.7%	85.5%	87.0%	2.2%
0.0%	0.1%	1.5%	5.4%	16.5%	31.0%	42.0%	65.4%	84.7%	85.5%	87.0%	2.3%
0.0%	0.1%	2.0%	8.3%	22.6%	38.1%	54.8%	84.4%	85.3%	86.6%	89.3%	3.0%
0.0%	0.3%	2.9%	13.1%	31.7%	49.6%	74.6%	84.8%	86.4%	88.7%	93.2%	4.0%
0.0%	0.4%	4.5%	19.1%	40.3%	69.4%	84.7%	85.7%	88.7%	92.7%	99.1%	5.3%
0.0%	0.6%	7.8%	28.7%	56.5%	84.6%	85.4%	87.4%	93.1%	99.0%	99.9%	7.0%
0.0%	1.6%	14.3%	39.7%	83.6%	85.4%	87.1%	91.3%	99.9%	99.9%	100.0%	9.1%
0.0%	1.6%	15.0%	40.9%	84.4%	85.5%	87.3%	91.9%	99.9%	99.9%	100.0%	9.2%
0.0%	1.7%	15.6%	42.2%	84.5%	85.6%	87.6%	92.4%	99.9%	100.0%	100.0%	9.3%
0.0%	1.8%	16.1%	43.6%	84.5%	85.7%	87.9%	93.0%	99.9%	100.0%	100.0%	9.5%
0.0%	1.8%	16.7%	45.1%	84.6%	85.9%	88.1%	93.6%	99.9%	100.0%	100.0%	9.6%
0.0%	1.9%	17.5%	46.7%	84.6%	86.0%	88.4%	94.2%	99.9%	100.0%	100.0%	9.7%

Type 2 (1)

TYPE 2: Platform with devices; Low-boy platform; Basic platform; Livestock; Automobile Transport; Oilfield; Grain; Tank truck for liquids or gases; Tank truck for dry bulk

Please enter one of the following alternative fuel types: LPG, CNG, Electricity (=Hybrid), Ethanol, Gasoline

Fuel Type	**Ethanol**
Discount Rate	**10.0%**
Annual VMT	225000
Fuel Efficiency Escalation Factor:	1.00

Year	Baseline Fuel Efficiency MPG	ADV. Diesel Efficiency Improvement	ADV. Diesel Adjusted MPG	Ethanol Efficiency Improvement	Ethanol Adjusted MPG	Ethanol Fuel Cost	**ANNUAL DOLLAR SAVINGS OF TECHNOLOGY** ADV. Diesel	Alt. Fuel	**NPV of Advanced Diesel Savings** Payback Periods (years) 1	2	3	4
1995	6.10	0.01	0.06	1.00	6.10	2.37	-4066943.68	-46337.79	-3697221.53	-3840500.98	-3882785.87	-3899621.07
1996	6.10	0.21	1.27	1.00	6.10	2.36	-173368.13	-41518.16	-157607.39	-204120.78	-222639.50	-229195.94
1997	6.79	0.41	2.76	1.00	6.79	2.36	-56281.20	-39734.95	-51164.73	-71535.32	-78747.40	-78747.40
1998	6.79	0.60	4.10	1.00	6.79	2.35	-24648.42	-40276.81	-22407.65	-30340.94	-30340.94	-27740.85
1999	6.79	0.80	5.45	1.00	6.79	2.34	-9599.28	-38658.57	-8726.62	-8726.62	-5866.51	-1333.95
2000	6.79	1.00	6.79	1.00	6.79	1.80	0.00	-9981.02	0.00	3146.11	8131.93	14071.42
2001	6.79	1.09	7.37	1.00	6.79	1.76	3806.80	-10381.72	3460.73	8945.12	15478.56	22923.36
2002	6.79	1.17	7.96	1.00	6.79	1.73	6636.12	-12042.45	6032.84	13219.62	21408.90	30118.59
2003	6.79	1.26	8.54	1.00	6.79	1.69	8696.00	-13666.30	7905.46	16913.67	26494.33	35394.28
2004	6.79	1.34	9.13	1.00	6.79	1.66	10899.93	-12289.03	9909.03	20447.76	30237.71	39553.83
2005	6.79	1.43	9.71	1.00	6.79	1.62	12751.86	-11274.54	11592.60	22361.55	32609.28	42010.14
2006	6.79	1.43	9.71	1.07	7.27	1.58	13030.42	-5721.36	11845.84	23118.35	33459.30	42907.78
2007	6.79	1.43	9.71	1.14	7.74	1.55	13639.73	363.53	12399.76	23774.80	34168.14	43739.08
2008	6.79	1.43	9.71	1.21	8.22	1.51	13763.81	4365.14	12512.55	23945.22	34473.26	44092.61
2009	6.79	1.43	9.71	1.28	8.69	1.48	13833.53	7793.46	12575.93	24156.78	34738.06	44301.26
2010	6.79	1.43	9.71	1.35	9.17	1.44	14012.82	11254.69	12738.93	24378.34	34897.85	44466.41
2011	6.79	1.43	9.71	1.45	9.86	1.43	14083.69	14201.57	12803.35	24374.82	34900.23	44400.43
2012	6.79	1.43	9.71	1.55	10.55	1.42	14001.47	16283.43	12728.61	24306.56	34756.78	44284.46
2013	6.79	1.43	9.71	1.66	11.24	1.41	14009.32	18374.69	12735.75	24230.99	34711.44	44206.89
2014	6.79	1.43	9.71	1.76	11.94	1.40	13909.24	19867.38	12644.77	24173.26	34618.26	44079.62
2015	6.79	1.43	9.71	1.86	12.63	1.39	13949.48	21626.50	12681.35	24170.85	34578.34	44044.87
2016	6.79	1.43	9.71	1.86	12.63	1.38	13902.29	21647.71	12638.45	24086.69	34499.87	43915.43
2017	6.79	1.43	9.71	1.86	12.63	1.37	13852.37	21659.86	12593.07	24047.57	34404.68	43828.55
2018	6.79	1.43	9.71	1.86	12.63	1.36	13859.94	21863.19	12599.95	23992.77	34359.03	43903.89
2019	6.79	1.43	9.71	1.86	12.63	1.35	13785.31	21793.16	12532.10	23934.99	34434.34	44100.18
2020	6.79	1.43	9.71	1.86	12.63	1.34	13797.50	22011.83	12543.18	24092.46	34724.88	44511.71
2021	6.79	1.43	9.71	1.86	12.63	1.34	13974.63	22600.90	12704.21	24399.88	35165.38	45073.19
2022	6.79	1.43	9.71	1.86	12.63	1.34	14151.76	23189.96	12865.24	24707.30	35605.89	45634.68
2023	6.79	1.43	9.71	1.86	12.63	1.34	14328.89	23779.03	13026.27	25014.71	36046.39	46208.90
2024	6.79	1.43	9.71	1.86	12.63	1.34	14506.02	24368.09	13187.29	25322.13	36500.89	46797.12
2025	6.79	1.43	9.71	1.86	12.63	1.34	14683.15	24957.16	13348.32	25644.96	36970.81	47400.75
2026	6.79	1.43	9.71	1.86	12.63	1.34	14878.93	25608.23	13526.30	25984.73	37457.67	48021.33
2027	6.79	1.43	9.71	1.86	12.63	1.34	15074.71	26259.29	13704.28	26324.51	37944.54	48641.92
2028	6.79	1.43	9.71	1.86	12.63	1.34	15270.48	26910.36	13882.26	26664.29	38431.40	49262.50
2029	6.79	1.43	9.71	1.86	12.63	1.34	15466.26	27561.43	14060.23	27004.06	38918.27	49883.08
2030	6.79	1.43	9.71	1.86	12.63	1.34	15662.03	28212.49	14238.21	27343.84	39405.13	50503.66
2031	6.79	1.43	9.71	1.86	12.63	1.34	15857.81	28863.56				
2032	6.79	1.43	9.71	1.86	12.63	1.34	16053.58	29514.63				
2033	6.79	1.43	9.71	1.86	12.63	1.34	16249.36	30165.69				
2034	6.79	1.43	9.71	1.86	12.63	1.34	16445.13	30816.76				
2035	6.79	1.43	9.71	1.86	12.63	1.34	16640.91	31467.83				

Type 2 (2)

NPV of Alternative Fuel Savings				Cost Effectiveness Factor Adv. Diesel					Cost Effectiveness Factor Alt. Fuels				
Payback Periods (years)				Payback Periods (years)				Tech	Payback Periods (years)				
1	2	3	4	1	2	3	4	Cost	1	2	3	4	
-42125.27	-76437.79	-106291.24	-133800.85	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.00
-37743.78	-70582.58	-100843.14	-127247.46	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-36122.68	-69409.30	-98454.05	-105271.22	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-36615.28	-68564.51	-76063.40	-83154.25	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-35144.15	-43392.93	-51192.87	-59418.02	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-9073.65	-17653.59	-26701.25	-36035.52	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-9437.93	-19390.36	-29658.05	-38051.63	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10947.68	-22242.14	-31475.07	-39175.73	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-12423.91	-22580.13	-31050.86	-34958.62	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-11171.85	-20489.64	-24788.19	-24539.89	0.00	0.00	-0.08	-0.41	100000	0.00	0.00	0.00	0.00	100.0
-10249.58	-14977.98	-14704.85	-11723.40	-0.16	-1.24	-2.26	-3.20	100000	0.00	0.00	0.00	0.00	82.7
-5201.24	-4900.80	-1621.20	3701.83	-0.25	-1.43	-2.52	-3.52	100000	0.00	0.00	0.00	0.00	72.0
330.48	3938.04	9793.38	17480.48	-0.38	-1.64	-2.80	-3.86	100000	0.00	0.00	0.00	0.00	54.1
3968.31	10409.19	18865.00	28564.86	-0.47	-1.82	-3.06	-4.19	100000	0.00	0.00	0.00	0.00	39.7
7084.96	16386.36	27056.20	38178.00	-0.57	-2.02	-3.34	-4.54	100000	0.00	0.00	0.00	0.00	22.8
10231.53	21968.37	34202.35	46752.51	-0.70	-2.25	-3.65	-4.93	100000	0.00	0.00	0.00	0.00	-1.1
12910.51	26367.89	40173.07	53742.76	-0.83	-2.48	-3.99	-5.34	100000	0.00	0.00	0.00	0.00	-29.1
14803.12	29988.81	44915.47	59686.66	-0.96	-2.74	-4.35	-5.81	100000	0.00	0.00	0.00	0.00	-60.7
16704.27	33123.59	49371.89	64157.57	-1.12	-3.04	-4.79	-6.37	100000	0.00	0.00	0.00	0.00	-107.3
18061.25	35934.39	52198.64	66992.62	-1.30	-3.40	-5.29	-7.01	100000	0.00	0.00	0.00	0.00	-166.6
19660.45	37551.12	53824.50	68757.35	-1.54	-3.83	-5.92	-7.81	100000	0.00	0.00	0.00	0.00	-264.7
19679.74	37580.45	54006.59	68891.61	-1.53	-3.82	-5.90	-7.78	100000	0.00	0.00	0.00	0.00	-260.8
19690.79	37759.54	54133.06	69167.44	-1.52	-3.81	-5.88	-7.77	100000	0.00	0.00	0.00	0.00	-256.6
19875.63	37886.51	54424.32	69861.03	-1.52	-3.80	-5.87	-7.78	100000	0.00	0.00	0.00	0.00	-257.2
19811.96	38003.56	54983.95	70823.00	-1.51	-3.79	-5.89	-7.82	100000	0.00	0.00	0.00	0.00	-251.1
20010.75	38689.18	56112.14	72353.54	-1.51	-3.82	-5.94	-7.90	100000	0.00	0.00	0.00	0.00	-252.1
20546.27	39711.53	57577.06	74220.80	-1.76	-4.30	-6.64	-8.80	100000	0.00	0.00	0.00	0.00	-382.3
21081.78	40733.87	59041.98	76088.06	-2.06	-4.88	-7.48	-9.87	100000	0.00	0.00	0.00	0.00	-587.1
21617.30	41756.22	60506.90	77997.66	-2.43	-5.58	-8.49	-11.16	100000	0.00	0.00	0.00	0.00	-933.6
22152.81	42778.56	62018.40	79953.85	-2.88	-6.45	-9.74	-12.76	100000	0.00	0.00	0.00	0.00	-1579.0
22688.33	43852.15	63581.14	81961.28	-3.45	-7.55	-11.32	-14.80	100000	0.00	0.00	0.00	0.00	-2948.3
23280.21	44982.10	65200.25	84025.08	-3.51	-7.66	-11.49	-15.01	100000	0.00	0.00	0.00	0.00	-3140.7
23872.08	46112.05	66819.36	86088.87	-3.57	-7.77	-11.65	-15.21	100000	0.00	0.00	0.00	0.00	-3344.9
24463.96	47242.00	68438.47	88152.67	-3.63	-7.89	-11.81	-15.42	100000	0.00	0.00	0.00	0.00	-3561.6
25055.84	48371.95	70057.57	90216.46	-3.69	-8.00	-11.97	-15.63	100000	0.00	0.00	0.00	0.00	-3791.5
25647.72	49501.90	71676.68	92280.26	-3.75	-8.11	-12.14	-15.83	100000	0.00	0.00	0.00	0.00	-4035.4

Type 2 (3)

Tech. Adoption Factor Adv. Diesel								Tech. Adoption Factor Alt. Fuels					
Payback Periods (years)								Payback Periods (years)					
1		2		3		4		1		2		3	
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	99.2	99.2	94.9	94.9	100.0	100.0	100.0	100.0	100.0	100.0	100.0
82.7	75.6	75.6	14.1	14.1	-135.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
72.0	68.1	68.1	-14.5	1.0	-226.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
54.1	58.4	58.4	-53.9	1.0	-364.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
39.7	48.5	48.5	-102.4	1.0	-548.5	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
22.8	34.6	34.6	-172.8	1.0	-824.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	15.1	15.1	-275.9	1.0	-1272.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-9.7	1.0	-428.3	1.0	-1981.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-44.8	1.0	-662.6	1.0	-3236.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-98.7	1.0	-1087.3	1.0	-5717.8	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-188.2	1.0	-1881.8	1.0	-11016.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-352.5	1.0	-3598.0	1.0	-24516.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-344.8	1.0	-3540.3	1.0	-23886.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-341.3	1.0	-3471.4	1.0	-23473.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-336.4	1.0	-3438.9	1.0	-23831.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-331.2	1.0	-3492.8	1.0	-24790.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-345.4	1.0	-3708.3	1.0	-26926.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-630.2	1.0	-7576.6	1.0	-66134.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-1209.9	1.0	-17569.8	1.0	-192415.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-2548.2	1.0	-48349.1	1.0	-702685.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-6202.4	1.0	-168972.5	1.0	-3493492.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-18865.5	1.0	-827409.5	1.0	-26771057.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-21141.1	1.0	-973217.7	1.0	-32923367.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-23689.5	1.0	-1144717.2	1.0	-40489547.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-26543.6	1.0	-1346434.8	1.0	-49794518.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-29740.0	1.0	-1583694.8	1.0	-61237875.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-33319.6	1.0	-1862759.7	1.0	-75311042.8	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Type 2 (4)

Market Penetration Advanced Diesel						Market Penetration Alternative Fuels					
16.4%	**61.7%**	**15.5%**	**6.4%**		adv	**16.4%**	**61.7%**	**15.5%**	**6.4%**		afv
Payback Periods (years)				Final	Final	Payback Periods (years)				Final	Final
1	2	3	4	Step 1	Step 2	1	2	3	4	Step 1	Step 2
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	1.2%	2.3%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.6%	13.6%	86.7%	99.8%	28.5%	28.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.2%	20.5%	99.4%	99.9%	34.8%	34.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.8%	31.4%	99.6%	100.0%	41.8%	41.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6.1%	43.9%	99.8%	100.0%	49.9%	49.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
12.1%	62.1%	99.9%	100.0%	62.2%	62.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
80.2%	85.7%	99.9%	100.0%	87.9%	87.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
84.0%	99.3%	100.0%	100.0%	96.9%	96.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
87.2%	99.6%	100.0%	100.0%	97.6%	97.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
90.4%	99.8%	100.0%	100.0%	98.3%	98.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.1%	99.9%	100.0%	100.0%	98.8%	98.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.6%	100.0%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.5%	100.0%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.4%	100.0%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.4%	99.9%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.3%	99.9%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
95.3%	100.0%	100.0%	100.0%	99.2%	99.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
97.1%	100.0%	100.0%	100.0%	99.5%	99.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
98.4%	100.0%	100.0%	100.0%	99.7%	99.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.2%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.7%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Type 2 (5)

Class 7-8 Type 2 Market Penetration by Average Annual VMT - Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.6%	2.8%	5.8%	8.4%	15.8%	28.5%	0.4%
0.0%	0.0%	0.0%	0.3%	0.6%	2.1%	3.8%	8.2%	11.8%	20.3%	34.8%	0.6%
0.0%	0.0%	0.1%	0.3%	1.5%	2.8%	5.3%	11.5%	15.7%	26.3%	41.8%	0.8%
0.0%	0.0%	0.1%	0.4%	1.8%	3.5%	7.0%	15.0%	19.3%	32.6%	49.9%	1.0%
0.0%	0.0%	0.1%	0.5%	2.2%	4.7%	9.5%	18.6%	24.2%	37.3%	62.2%	1.3%
0.0%	0.0%	0.1%	0.6%	2.9%	6.3%	12.9%	23.4%	30.7%	44.7%	87.9%	1.8%
0.0%	0.0%	0.3%	1.4%	3.8%	8.6%	16.7%	29.5%	36.1%	54.7%	96.9%	2.3%
0.0%	0.0%	0.4%	1.8%	5.1%	11.8%	20.8%	35.4%	42.5%	70.0%	97.6%	2.8%
0.0%	0.0%	0.4%	2.3%	7.2%	16.0%	27.0%	42.1%	53.0%	95.2%	98.3%	3.5%
0.0%	0.0%	0.6%	3.1%	10.5%	21.0%	34.5%	53.5%	70.7%	97.4%	98.8%	4.5%
0.0%	0.1%	1.4%	4.6%	15.5%	28.8%	42.6%	76.0%	96.8%	98.3%	99.2%	6.1%
0.0%	0.1%	1.4%	4.5%	15.4%	28.5%	42.3%	74.6%	96.7%	98.2%	99.2%	6.0%
0.0%	0.1%	1.4%	4.5%	15.3%	28.3%	42.1%	73.7%	96.7%	98.2%	99.2%	6.0%
0.0%	0.1%	1.4%	4.5%	15.2%	28.1%	41.8%	73.3%	96.7%	98.2%	99.2%	6.0%
0.0%	0.1%	1.4%	4.6%	15.3%	28.1%	41.6%	72.1%	96.7%	98.2%	99.2%	5.9%
0.0%	0.1%	1.4%	4.7%	15.6%	28.9%	42.3%	73.5%	96.7%	98.2%	99.2%	6.1%
0.0%	0.1%	1.9%	7.2%	21.2%	36.4%	55.7%	96.9%	97.7%	98.8%	99.5%	7.7%
0.0%	0.3%	2.7%	11.4%	29.8%	47.0%	86.3%	97.9%	98.5%	99.3%	99.7%	10.1%
0.0%	0.4%	4.2%	17.3%	38.6%	67.2%	97.3%	98.7%	99.1%	99.6%	99.9%	12.4%
0.0%	0.6%	7.3%	25.8%	54.0%	96.9%	98.3%	99.3%	99.5%	99.8%	99.9%	15.6%
0.0%	1.6%	13.4%	37.0%	92.2%	98.2%	99.1%	99.6%	99.8%	99.9%	100.0%	18.9%
0.0%	1.6%	14.1%	38.1%	94.9%	98.3%	99.2%	99.7%	99.8%	99.9%	100.0%	19.2%
0.0%	1.7%	14.9%	39.3%	96.6%	98.4%	99.2%	99.7%	99.8%	99.9%	100.0%	19.4%
0.0%	1.8%	15.4%	40.5%	96.8%	98.5%	99.3%	99.7%	99.8%	99.9%	100.0%	19.5%
0.0%	1.9%	15.9%	41.8%	96.9%	98.5%	99.3%	99.7%	99.8%	100.0%	100.0%	19.7%
0.0%	1.9%	16.5%	43.1%	97.0%	98.6%	99.4%	99.8%	99.9%	100.0%	100.0%	19.8%

Type 2 (6)

Class 7-8 Type 2 Market Penetration by Average Annual VMT - Non-Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.6%	2.9%	5.6%	8.4%	14.0%	28.5%	0.8%
0.0%	0.0%	0.0%	0.3%	0.6%	2.1%	4.0%	7.8%	11.8%	17.7%	34.8%	1.1%
0.0%	0.0%	0.1%	0.4%	1.5%	2.7%	5.5%	11.0%	15.7%	22.9%	41.8%	1.5%
0.0%	0.0%	0.1%	0.4%	1.8%	3.5%	7.3%	14.5%	19.3%	28.5%	49.9%	2.0%
0.0%	0.0%	0.1%	0.5%	2.2%	4.6%	9.9%	18.0%	24.2%	34.4%	62.2%	2.5%
0.0%	0.0%	0.1%	0.7%	2.9%	6.2%	13.4%	22.6%	30.7%	40.2%	87.9%	3.4%
0.0%	0.0%	0.3%	1.5%	3.8%	8.4%	17.1%	28.5%	36.1%	48.3%	96.9%	4.4%
0.0%	0.0%	0.3%	1.8%	5.1%	11.5%	21.4%	34.7%	42.5%	60.4%	97.6%	5.5%
0.0%	0.0%	0.4%	2.4%	7.2%	15.7%	27.8%	41.0%	53.0%	86.6%	98.3%	7.2%
0.0%	0.0%	0.5%	3.3%	10.5%	20.6%	35.1%	51.8%	70.7%	97.0%	98.8%	9.2%
0.0%	0.1%	1.3%	4.8%	15.5%	28.2%	43.6%	72.1%	96.8%	97.9%	99.2%	12.3%
0.0%	0.1%	0.7%	4.8%	15.4%	28.0%	43.2%	71.0%	96.7%	97.9%	99.2%	12.1%
0.0%	0.1%	0.7%	4.7%	15.3%	27.8%	43.0%	70.4%	96.7%	97.9%	99.2%	12.0%
0.0%	0.1%	0.7%	4.7%	15.2%	27.6%	42.8%	70.0%	96.7%	97.9%	99.2%	12.0%
0.0%	0.1%	0.7%	4.8%	15.2%	27.6%	42.5%	69.0%	96.7%	97.8%	99.2%	11.9%
0.0%	0.1%	0.8%	5.0%	15.6%	28.3%	43.2%	70.4%	96.7%	97.9%	99.2%	12.2%
0.0%	0.1%	1.8%	7.6%	21.1%	36.0%	57.3%	96.7%	97.7%	98.6%	99.5%	15.9%
0.0%	0.1%	2.6%	12.0%	29.8%	46.2%	89.0%	97.8%	98.5%	99.1%	99.7%	21.3%
0.0%	0.3%	4.0%	17.9%	38.6%	65.8%	97.4%	98.6%	99.1%	99.5%	99.9%	25.8%
0.0%	0.5%	6.9%	26.8%	53.9%	96.8%	98.4%	99.2%	99.5%	99.8%	99.9%	31.7%
0.0%	1.4%	12.7%	37.9%	92.1%	98.1%	99.1%	99.6%	99.8%	99.9%	100.0%	35.8%
0.0%	1.4%	13.5%	39.1%	94.9%	98.2%	99.2%	99.7%	99.8%	99.9%	100.0%	36.2%
0.0%	1.5%	14.2%	40.3%	96.6%	98.3%	99.2%	99.7%	99.8%	99.9%	100.0%	36.4%
0.0%	1.6%	14.9%	41.6%	96.8%	98.4%	99.3%	99.7%	99.8%	99.9%	100.0%	36.6%
0.0%	1.6%	15.4%	43.0%	96.9%	98.5%	99.3%	99.7%	99.8%	99.9%	100.0%	36.7%
0.0%	1.7%	16.0%	44.4%	97.0%	98.6%	99.4%	99.7%	99.9%	99.9%	100.0%	36.8%

Type 3 (1)

TYPE 3: Insulated; Non-refrigerated; Insulated Refrigerated; Drop Frame, Open Top, Basic Enclosed

Please enter one of the following alternative fuel types: LPG, CNG, Electricity, Ethanol, Gasoline

Fuel Type	**Ethanol**
Discount Rate	**10.0%**
Annual VMT	218113

	Fuel Efficiency Escalation Factor:	1.00										
	Baseline Fuel Efficiency	ADV. Diesel Efficiency	ADV. Diesel Adjusted	Ethanol Efficiency	Ethanol Adjusted	Ethanol Fuel	**ANNUAL DOLLAR SAVINGS OF TECHNOLOGY**		**NPV of Advanced Diesel Savings** Payback Periods (years)			
Year	MPG	Improvement	MPG	Improvement	MPG	Cost	ADV. Diesel	Alt. Fuel	1	2	3	4
1995	7.00	0.01	0.07	1.00	7.00	2.37	-3435577.02	-39144.15	-3123251.84	-3244288.08	-3284049.03	-3299879.35
1996	7.00	0.21	1.46	1.00	7.00	2.36	-146453.85	-35072.73	-133139.87	-176876.91	-194290.27	-200455.36
1997	7.00	0.41	2.84	1.00	7.00	2.36	-52921.83	-37363.20	-48110.75	-67265.44	-74047.04	-74047.04
1998	7.00	0.60	4.23	1.00	7.00	2.35	-23177.18	-37872.72	-21070.16	-28529.92	-28529.92	-26085.02
1999	7.00	0.80	5.61	1.00	7.00	2.34	-9026.31	-36351.07	-8205.73	-8205.73	-5516.35	-1254.33
2000	7.00	1.00	7.00	1.00	7.00	1.80	0.00	-9385.26	0.00	2958.33	7646.54	13231.51
2001	7.00	1.09	7.60	1.00	7.00	1.76	3579.57	-9762.04	3254.16	8411.20	14554.66	21555.09
2002	7.00	1.17	8.20	1.00	7.00	1.73	6240.02	-11323.64	5672.74	12430.55	20131.02	28186.71
2003	7.00	1.26	8.81	1.00	7.00	1.69	8176.95	-12850.57	7433.59	15904.11	24765.37	33134.09
2004	7.00	1.34	9.41	1.00	7.00	1.66	10249.33	-11555.51	9317.57	19064.95	28270.55	37030.60
2005	7.00	**1.42**	**9.94**	**1.00**	**7.00**	**1.62**	11794.34	-10601.57	10722.12	20848.28	30484.34	39324.07
2006	7.00	1.43	10.01	1.07	7.49	1.58	12252.65	-5379.86	11138.77	21738.43	31462.14	40346.66
2007	7.00	1.43	10.01	1.14	7.98	1.55	12825.59	341.83	11659.63	22355.71	32128.67	41128.34
2008	7.00	1.43	10.01	1.21	8.47	1.51	12942.26	4104.59	11765.69	22515.95	32415.58	41460.76
2009	7.00	1.43	10.01	1.28	8.96	1.48	13007.82	7328.27	11825.29	22714.88	32664.58	41656.95
2010	7.00	1.43	10.01	1.35	9.45	1.44	13176.41	10582.91	11978.55	22923.22	32814.83	41812.25
2011	7.00	1.43	10.01	1.45	10.16	1.43	13243.05	13353.89	12039.13	22919.91	32817.06	41750.20
2012	7.00	1.43	10.01	1.55	10.88	1.42	13165.73	15311.49	11968.85	22855.72	32682.18	41641.16
2013	7.00	1.43	10.01	1.66	11.59	1.41	13173.12	17277.92	11975.56	22784.66	32639.55	41568.22
2014	7.00	1.43	10.01	1.76	12.31	1.40	13079.01	18681.51	11890.01	22730.38	32551.93	41448.55
2015	7.00	**1.43**	**10.01**	**1.86**	**13.02**	**1.39**	13116.85	20335.63	11924.41	22728.11	32514.39	41415.87
2016	7.00	1.43	10.01	1.86	13.02	1.38	13072.48	20355.58	11884.07	22648.98	32440.61	41294.15
2017	7.00	1.43	10.01	1.86	13.02	1.37	13025.54	20367.01	11841.40	22612.19	32351.09	41212.47
2018	7.00	1.43	10.01	1.86	13.02	1.36	13032.66	20558.20	11847.87	22560.66	32308.17	41283.31
2019	7.00	1.43	10.01	1.86	13.02	1.35	12962.48	20492.35	11784.07	22506.34	32378.98	41467.88
2020	7.00	1.43	10.01	1.86	13.02	1.34	12973.94	20697.96	11794.49	22654.40	32652.19	41854.85
2021	7.00	1.43	10.01	1.86	13.02	1.34	13140.50	21251.87	11945.90	22943.47	33066.39	42382.82
2022	7.00	1.43	10.01	1.86	13.02	1.34	13307.05	21805.77	12097.32	23232.54	33480.60	42910.78
2023	7.00	1.43	10.01	1.86	13.02	1.34	13473.61	22359.68	12248.74	23521.61	33894.81	43450.73
2024	7.00	1.43	10.01	1.86	13.02	1.34	13640.17	22913.58	12400.16	23810.68	34322.19	44003.84
2025	7.00	1.43	10.01	1.86	13.02	1.34	13806.73	23467.49	12551.57	24114.23	34764.05	44571.44
2026	7.00	1.43	10.01	1.86	13.02	1.34	13990.82	24079.69	12718.93	24433.73	35221.86	45154.98
2027	7.00	1.43	10.01	1.86	13.02	1.34	14174.91	24691.90	12886.28	24753.22	35679.66	45738.52
2028	7.00	1.43	10.01	1.86	13.02	1.34	14359.00	25304.10	13053.64	25072.72	36137.47	46322.06
2029	7.00	1.43	10.01	1.86	13.02	1.34	14543.09	25916.31	13220.99	25392.21	36595.27	46905.60
2030	7.00	1.43	10.01	1.86	13.02	1.34	14727.18	26528.52	13388.34	25711.71	37053.07	47489.14
2031	7.00	1.43	10.01	1.86	13.02	1.34	14911.27	27140.72				
2032	7.00	1.43	10.01	1.86	13.02	1.34	15095.36	27752.93				
2033	7.00	1.43	10.01	1.86	13.02	1.34	15279.45	28365.13				
2034	7.00	1.43	10.01	1.86	13.02	1.34	15463.54	28977.34				
2035	7.00	1.43	10.01	1.86	13.02	1.34	15647.63	29589.54				

Type 3 (2)

NPV of Alternative Fuel Savings				Cost Effectiveness Factor Adv. Diesel					Cost Effectiveness Factor Alt. Fuels				
Payback Periods (years)				Payback Periods (years)				Tech	Payback Periods (years)				
1	2	3	4	1	2	3	4	Cost	1	2	3	4	
-35585.59	-64571.32	-92642.85	-118510.43	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.00
-31884.30	-62762.98	-91217.32	-116045.59	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-33966.55	-65266.32	-92577.42	-98987.68	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-34429.75	-64471.96	-71523.24	-78190.85	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-33046.43	-40802.84	-48137.21	-55871.41	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-8532.05	-16599.86	-25107.48	-33884.59	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-8874.59	-18232.97	-27887.79	-35780.36	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10294.22	-20914.53	-29596.35	-36837.37	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-11682.34	-21232.34	-29197.46	-32871.97	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-10505.01	-19266.64	-23308.60	-23075.13	0.00	0.00	-0.01	-0.32	100000	0.00	0.00	0.00	0.00	100.0
-9637.79	-14083.95	-13827.13	-11023.64	-0.07	-1.08	-2.05	-2.93	100000	0.00	0.00	0.00	0.00	92.5
-4890.78	-4608.27	-1524.43	3480.87	-0.17	-1.29	-2.31	-3.25	100000	0.00	0.00	0.00	0.00	81.2
310.75	3702.98	9208.82	16437.09	-0.30	-1.48	-2.57	-3.57	100000	0.00	0.00	0.00	0.00	65.6
3731.45	9787.87	17738.96	26859.85	-0.38	-1.65	-2.81	-3.88	100000	0.00	0.00	0.00	0.00	53.2
6662.07	15408.27	25441.24	35899.19	-0.48	-1.84	-3.08	-4.21	100000	0.00	0.00	0.00	0.00	38.7
9620.82	20657.09	32160.84	43961.89	-0.60	-2.06	-3.38	-4.57	100000	0.00	0.00	0.00	0.00	18.3
12139.90	24794.02	37775.18	50534.90	-0.72	-2.27	-3.69	-4.96	100000	0.00	0.00	0.00	0.00	-5.4
13919.53	28198.81	42234.50	56124.01	-0.84	-2.52	-4.03	-5.41	100000	0.00	0.00	0.00	0.00	-32.0
15707.20	31146.47	46424.93	60328.06	-1.00	-2.80	-4.44	-5.93	100000	0.00	0.00	0.00	0.00	-70.7
16983.19	33789.50	49082.95	62993.89	-1.16	-3.13	-4.92	-6.54	100000	0.00	0.00	0.00	0.00	-119.6
18486.94	35309.73	50611.76	64653.29	-1.38	-3.55	-5.50	-7.28	100000	0.00	0.00	0.00	0.00	-199.4
18505.07	35337.31	50782.99	64779.54	-1.38	-3.53	-5.49	-7.26	100000	0.00	0.00	0.00	0.00	-196.2
18515.46	35505.71	50901.91	65038.90	-1.37	-3.52	-5.47	-7.24	100000	0.00	0.00	0.00	0.00	-192.9
18689.27	35625.09	51175.78	65691.09	-1.37	-3.51	-5.46	-7.26	100000	0.00	0.00	0.00	0.00	-193.4
18629.41	35735.16	51702.00	66595.64	-1.36	-3.50	-5.48	-7.29	100000	0.00	0.00	0.00	0.00	-188.4
18816.33	36379.86	52762.86	68034.82	-1.36	-3.53	-5.53	-7.37	100000	0.00	0.00	0.00	0.00	-189.2
19319.88	37341.18	54140.34	69790.62	-1.60	-3.99	-6.19	-8.21	100000	0.00	0.00	0.00	0.00	-293.8
19823.43	38302.50	55517.82	71546.43	-1.88	-4.53	-6.97	-9.22	100000	0.00	0.00	0.00	0.00	-455.6
20326.98	39263.83	56895.30	73342.05	-2.22	-5.19	-7.92	-10.43	100000	0.00	0.00	0.00	0.00	-723.8
20830.53	40225.15	58316.58	75181.48	-2.65	-6.00	-9.09	-11.94	100000	0.00	0.00	0.00	0.00	-1211.3
21334.08	41234.65	59786.04	77069.09	-3.18	-7.04	-10.59	-13.86	100000	0.00	0.00	0.00	0.00	-2214.0
21890.63	42297.16	61308.51	79009.70	-3.24	-7.14	-10.74	-14.05	100000	0.00	0.00	0.00	0.00	-2352.5
22447.18	43359.66	62830.97	80950.30	-3.30	-7.25	-10.89	-14.25	100000	0.00	0.00	0.00	0.00	-2498.9
23003.73	44422.17	64353.44	82890.91	-3.35	-7.36	-11.05	-14.44	100000	0.00	0.00	0.00	0.00	-2653.7
23560.28	45484.67	65875.90	84831.52	-3.41	-7.46	-11.20	-14.64	100000	0.00	0.00	0.00	0.00	-2817.4
24116.83	46547.18	67398.36	86772.13	-3.46	-7.57	-11.35	-14.83	100000	0.00	0.00	0.00	0.00	-2990.6

Type 3 (3)

Tech. Adoption Factor Adv. Diesel								Tech. Adoption Factor Alt. Fuels							
Payback Periods (years)								Payback Periods (years)							
1		2		3		4		1		2		3		4	
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	99.9	99.9	96.2	96.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
92.5	80.4	80.4	32.4	32.4	-77.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
81.2	73.7	73.7	9.1	9.1	-147.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
65.6	65.9	65.9	-20.6	1.0	-245.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
53.2	58.0	58.0	-56.7	1.0	-373.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
38.7	47.1	47.1	-108.3	1.0	-561.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
18.3	31.8	31.8	-182.3	1.0	-860.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	12.8	12.8	-289.7	1.0	-1322.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-13.8	1.0	-451.5	1.0	-2118.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-54.0	1.0	-737.7	1.0	-3644.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-119.4	1.0	-1258.0	1.0	-6785.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-236.6	1.0	-2344.0	1.0	-14446.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-231.2	1.0	-2308.0	1.0	-14095.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-228.7	1.0	-2265.1	1.0	-13865.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-225.2	1.0	-2244.8	1.0	-14065.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-221.6	1.0	-2278.4	1.0	-14598.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-231.5	1.0	-2412.5	1.0	-15781.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-429.3	1.0	-4760.4	1.0	-36800.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-819.0	1.0	-10549.0	1.0	-100543.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-1684.5	1.0	-27399.1	1.0	-339987.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-3937.0	1.0	-88975.0	1.0	-1536196.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-11282.0	1.0	-396458.2	1.0	-10425055.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-12562.1	1.0	-461836.6	1.0	-12663543.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-13986.2	1.0	-537993.3	1.0	-15382677.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-15570.3	1.0	-626705.3	1.0	-18685662.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-17332.3	1.0	-730042.3	1.0	-22697863.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-19292.4	1.0	-850415.6	1.0	-27571561.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Type 3 (4)

Market Penetration Advanced Diesel						Market Penetration Alternative Fuels					
16.4%	**61.7%**	**15.5%**	**6.4%**			**16.4%**	**61.7%**	**15.5%**	**6.4%**		
Payback Periods (years)				Final	Final	Payback Periods (years)				Final	Final
1	2	3	4	Step 1	Step 2	1	2	3	4	Step 1	Step 2
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	1.0%	1.9%	0.3%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.2%	9.8%	65.0%	99.7%	22.7%	22.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.7%	15.1%	91.8%	99.8%	30.2%	30.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.7%	22.8%	99.4%	99.9%	36.3%	36.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.9%	31.8%	99.6%	100.0%	42.1%	42.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
6.3%	45.7%	99.8%	100.0%	51.1%	51.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15.3%	65.8%	99.9%	100.0%	65.0%	65.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
80.8%	88.1%	99.9%	100.0%	89.5%	89.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
84.3%	99.4%	100.0%	100.0%	97.0%	97.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
88.0%	99.6%	100.0%	100.0%	97.8%	97.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
91.1%	99.8%	100.0%	100.0%	98.4%	98.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
94.1%	99.9%	100.0%	100.0%	99.0%	99.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
94.0%	99.9%	100.0%	100.0%	99.0%	99.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.9%	99.9%	100.0%	100.0%	98.9%	98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.9%	99.9%	100.0%	100.0%	98.9%	98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.8%	99.9%	100.0%	100.0%	98.9%	98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
93.8%	99.9%	100.0%	100.0%	98.9%	98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
96.1%	100.0%	100.0%	100.0%	99.3%	99.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
97.7%	100.0%	100.0%	100.0%	99.6%	99.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
98.8%	100.0%	100.0%	100.0%	99.8%	99.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.5%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.8%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.8%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Type 3 (5)

Class 7-8 Type 3 Market Penetration by Average Annual VMT - Centrally Refueled Advanced Diesels

(thousands of miles)

0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Final Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%
0.0%	0.0%	0.0%	0.1%	0.4%	1.4%	2.5%	4.8%	8.2%	14.4%	20.8%	0.8%
0.0%	0.0%	0.0%	0.3%	0.6%	1.8%	3.4%	6.8%	11.8%	18.6%	27.7%	1.1%
0.0%	0.0%	0.0%	0.3%	0.7%	2.4%	4.7%	9.6%	15.8%	24.0%	34.4%	1.5%
0.0%	0.0%	0.1%	0.4%	1.6%	3.0%	6.2%	12.8%	19.4%	29.8%	39.4%	1.9%
0.0%	0.0%	0.1%	0.5%	2.0%	4.0%	8.4%	16.2%	24.4%	35.3%	47.1%	2.3%
0.0%	0.0%	0.1%	0.6%	2.5%	5.3%	11.5%	20.4%	30.9%	41.6%	59.2%	3.0%
0.0%	0.0%	0.3%	1.4%	3.3%	7.2%	15.3%	25.7%	36.2%	50.3%	78.7%	3.9%
0.0%	0.0%	0.3%	1.8%	4.4%	10.0%	19.0%	32.5%	42.7%	63.3%	96.7%	4.9%
0.0%	0.0%	0.4%	2.3%	6.1%	14.0%	24.7%	38.2%	53.3%	89.5%	97.6%	6.2%
0.0%	0.0%	0.5%	3.1%	9.0%	18.5%	32.6%	47.3%	71.2%	97.2%	98.2%	7.7%
0.0%	0.1%	0.7%	4.5%	13.6%	25.3%	39.8%	64.1%	96.8%	98.1%	98.8%	9.6%
0.0%	0.1%	0.7%	4.5%	13.4%	25.1%	39.5%	63.3%	96.8%	98.0%	98.8%	9.6%
0.0%	0.1%	0.7%	4.4%	13.3%	24.9%	39.3%	62.9%	96.7%	98.0%	98.8%	9.5%
0.0%	0.1%	0.7%	4.4%	13.3%	24.7%	39.1%	62.5%	96.7%	98.0%	98.8%	9.5%
0.0%	0.1%	0.7%	4.5%	13.4%	24.8%	38.9%	61.9%	96.7%	98.0%	98.8%	9.5%
0.0%	0.1%	0.7%	4.6%	13.8%	25.4%	39.5%	63.1%	96.7%	98.0%	98.8%	9.6%
0.0%	0.1%	1.7%	7.1%	18.9%	33.8%	51.2%	93.5%	97.7%	98.6%	99.2%	12.0%
0.0%	0.1%	2.3%	11.2%	26.5%	42.4%	72.7%	97.5%	98.5%	99.2%	99.6%	14.9%
0.0%	0.3%	3.6%	17.0%	35.8%	59.0%	97.0%	98.4%	99.1%	99.5%	99.8%	18.7%
0.0%	0.5%	6.0%	25.4%	48.5%	95.0%	98.1%	99.1%	99.5%	99.8%	99.9%	22.4%
0.0%	1.4%	11.1%	36.7%	78.5%	97.9%	99.0%	99.6%	99.8%	99.9%	#####	25.3%
0.0%	1.4%	11.8%	37.7%	87.8%	98.0%	99.0%	99.6%	99.8%	99.9%	#####	26.0%
0.0%	1.5%	12.5%	38.9%	90.2%	98.1%	99.1%	99.6%	99.8%	99.9%	#####	26.2%
0.0%	1.6%	13.1%	40.0%	92.9%	98.2%	99.2%	99.6%	99.8%	99.9%	#####	26.5%
0.0%	1.6%	13.8%	41.3%	95.5%	98.3%	99.2%	99.7%	99.8%	99.9%	#####	26.7%
0.0%	1.7%	14.6%	42.6%	96.6%	98.4%	99.3%	99.7%	99.9%	99.9%	#####	26.9%

Type 3 (6)

Class 7-8 Type 3 Market Penetration by Average Annual VMT - Non-Centrally Refueled Advanced Diesels

(thousands of miles)

0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Final Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.3%	0.0%
0.0%	0.0%	0.0%	0.1%	0.5%	1.5%	2.6%	5.0%	8.6%	12.9%	22.7%	1.6%
0.0%	0.0%	0.0%	0.3%	0.6%	1.9%	3.6%	7.1%	12.3%	17.0%	30.2%	2.2%
0.0%	0.0%	0.1%	0.3%	0.7%	2.5%	4.9%	10.0%	16.2%	22.0%	36.3%	2.9%
0.0%	0.0%	0.1%	0.4%	1.6%	3.2%	6.5%	13.3%	20.0%	27.4%	42.1%	3.7%
0.0%	0.0%	0.1%	0.5%	2.0%	4.2%	8.8%	16.8%	25.1%	33.6%	51.1%	4.7%
0.0%	0.0%	0.1%	0.6%	2.6%	5.7%	12.0%	21.1%	31.8%	39.0%	65.0%	6.1%
0.0%	0.0%	0.3%	0.7%	3.3%	7.7%	15.7%	26.6%	36.9%	46.6%	89.5%	7.9%
0.0%	0.0%	0.3%	1.7%	4.4%	10.6%	19.6%	33.4%	43.7%	57.9%	97.0%	9.6%
0.0%	0.0%	0.4%	2.1%	6.2%	14.8%	25.4%	39.1%	54.8%	79.9%	97.8%	11.7%
0.0%	0.0%	0.5%	2.9%	9.1%	19.3%	33.4%	48.8%	74.0%	96.9%	98.4%	14.6%
0.0%	0.1%	1.3%	4.2%	13.8%	26.5%	40.7%	66.5%	96.9%	97.8%	99.0%	18.2%
0.0%	0.1%	0.7%	4.1%	13.6%	26.2%	40.4%	65.7%	96.9%	97.8%	99.0%	18.0%
0.0%	0.1%	0.7%	4.1%	13.5%	26.0%	40.2%	65.2%	96.8%	97.8%	98.9%	18.0%
0.0%	0.1%	0.7%	4.1%	13.5%	25.9%	40.0%	64.8%	96.8%	97.8%	98.9%	17.9%
0.0%	0.1%	0.7%	4.1%	13.6%	25.9%	39.8%	64.1%	96.8%	97.7%	98.9%	17.8%
0.0%	0.1%	0.8%	4.3%	14.1%	26.6%	40.4%	65.4%	96.8%	97.8%	98.9%	18.1%
0.0%	0.1%	1.8%	6.5%	19.1%	34.7%	52.6%	95.6%	97.8%	98.5%	99.3%	22.6%
0.0%	0.1%	2.6%	10.4%	26.9%	43.9%	75.8%	97.6%	98.5%	99.1%	99.6%	27.5%
0.0%	0.3%	4.0%	16.0%	36.1%	61.6%	97.1%	98.5%	99.1%	99.5%	99.8%	33.0%
0.0%	0.5%	6.9%	23.9%	49.1%	96.6%	98.2%	99.1%	99.5%	99.7%	99.9%	37.8%
0.0%	0.8%	12.7%	35.4%	80.6%	98.0%	99.0%	99.6%	99.8%	99.9%	100.0%	41.2%
0.0%	1.4%	13.5%	36.3%	88.3%	98.1%	99.1%	99.6%	99.8%	99.9%	100.0%	41.9%
0.0%	1.5%	14.2%	37.4%	91.1%	98.2%	99.1%	99.6%	99.8%	99.9%	100.0%	42.2%
0.0%	1.5%	14.9%	38.4%	93.8%	98.3%	99.2%	99.7%	99.8%	99.9%	100.0%	42.5%
0.0%	1.6%	15.4%	39.6%	96.4%	98.4%	99.2%	99.7%	99.9%	99.9%	100.0%	42.8%
0.0%	1.7%	16.0%	40.8%	96.7%	98.5%	99.3%	99.7%	99.9%	99.9%	100.0%	42.9%

Med (1)

Classes 3-6

Please enter one of the following alternative fuel types: LPG, CNG, Electricity, Ethanol, Gasoline

Fuel Type	**Ethanol**
Discount Rate	**10.0%**
Annual VMT	212500

Year	Baseline Fuel Efficiency MPG	ADV. Diesel Efficiency Improvement	ADV. Diesel Adjusted MPG	Ethanol Efficiency Improvement	Ethanol Adjusted MPG	Ethanol Fuel Cost	**ANNUAL DOLLAR SAVINGS OF TECHNOLOGY** ADV. Diesel	Alt. Fuel	**NPV of Advanced Diesel Savings** Payback Periods (years) 1	2	3	4
1995	8.82	1.00	8.82	1.00	8.82	2.37	0.00	-30269.13	0.00	0.00	0.00	0.00
1996	8.86	1.00	8.86	1.00	8.86	2.36	0.00	-26997.80	0.00	0.00	0.00	0.00
1997	8.90	1.00	8.90	1.00	8.90	2.36	0.00	-28630.49	0.00	0.00	0.00	0.00
1998	8.92	1.00	8.92	1.00	8.92	2.35	0.00	-28964.24	0.00	0.00	0.00	3890.66
1999	8.94	1.00	8.94	1.00	8.94	2.34	0.00	-27722.96	0.00	0.00	4279.73	10539.81
2000	9.00	1.00	9.00	1.00	9.00	1.80	0.00	-7111.78	0.00	4707.70	11593.79	19281.49
2001	9.02	1.20	10.82	1.20	10.82	1.76	5696.32	-454.63	5178.47	12753.17	21209.64	30340.63
2002	9.04	1.40	12.66	1.40	12.66	1.73	9165.38	3063.11	8332.16	17634.29	27678.37	37885.35
2003	9.06	1.60	14.49	1.60	14.49	1.69	11255.57	5209.32	10232.34	21280.83	32508.51	42915.68
2004	9.08	1.80	16.34	1.80	16.34	1.66	13368.68	8546.41	12153.34	24503.79	35951.68	46821.71
2005	9.10	2.00	18.20	2.00	18.20	1.62	14944.04	10970.97	13585.49	26178.17	38135.21	49080.17
2006	9.12	2.00	18.24	2.10	19.15	1.58	15237.15	12896.83	13851.95	27004.69	39044.15	50020.53
2007	9.14	2.00	18.28	2.20	20.11	1.55	15914.81	15468.28	14468.01	27711.41	39785.43	50879.80
2008	9.16	2.00	18.32	2.30	21.07	1.51	16024.52	16796.38	14567.74	27849.16	40052.97	51179.09
2009	9.18	2.00	18.36	2.40	22.03	1.48	16070.52	17903.10	14609.56	28033.75	40272.49	51309.51
2010	9.20	2.00	18.40	2.50	23.00	1.44	16243.26	19180.60	14766.60	28229.22	40369.94	51389.03
2011	9.22	2.00	18.44	2.50	23.05	1.43	16289.76	19394.85	14808.87	28163.67	40284.67	51201.16
2012	9.24	2.00	18.48	2.50	23.10	1.42	16159.30	19254.71	14690.27	28023.38	40031.51	50955.68
2013	9.26	2.00	18.52	2.50	23.15	1.41	16133.06	19322.55	14666.41	27875.36	39891.94	50755.38
2014	9.28	2.00	18.56	2.50	23.20	1.40	15982.83	19141.96	14529.84	27748.08	39697.86	50498.65
2015	9.30	2.00	18.60	2.50	23.25	1.39	15994.07	19283.84	14540.06	27684.82	39565.69	50348.78
2016	9.32	2.00	18.64	2.50	23.30	1.38	15905.15	19224.95	14459.23	27528.19	39389.59	50091.21
2017	9.34	2.00	18.68	2.50	23.35	1.37	15813.44	19160.00	14375.85	27423.40	39195.18	49882.86
2018	9.36	2.00	18.72	2.50	23.40	1.36	15787.53	19226.20	14352.30	27301.25	39057.71	49828.74
2019	9.38	2.00	18.76	2.50	23.45	1.35	15668.23	19105.18	14243.85	27175.95	39024.09	49877.38
2020	9.40	2.00	18.80	2.50	23.51	1.34	15647.84	19181.50	14225.31	27258.26	39196.88	50131.35
2021	9.45	2.00	18.90	2.50	23.62	1.34	15769.87	19485.84	14336.25	27468.74	39496.65	50511.22
2022	9.50	2.00	18.99	2.50	23.74	1.34	15890.31	19786.68	14445.74	27676.44	39792.47	50886.06
2023	9.54	2.00	19.09	2.50	23.86	1.34	16009.16	20084.04	14553.78	27881.40	40084.36	51269.94
2024	9.59	2.00	19.18	2.50	23.98	1.34	16126.43	20377.96	14660.39	28083.64	40387.78	51664.16
2025	9.64	2.00	19.28	2.50	24.10	1.34	16242.13	20668.45	14765.58	28300.13	40704.15	52070.14
2026	9.69	2.00	19.38	2.50	24.22	1.34	16376.81	20996.59	14888.01	28532.43	41035.03	52489.47
2027	9.74	2.00	19.47	2.50	24.34	1.34	16509.75	21320.96	15008.86	28761.72	41361.60	52903.33
2028	9.78	2.00	19.57	2.50	24.46	1.34	16640.95	21641.57	15128.14	28988.02	41683.91	53311.77
2029	9.83	2.00	19.67	2.50	24.58	1.34	16770.45	21958.47	15245.86	29211.35	42001.99	53714.84
2030	9.88	2.00	19.77	2.50	24.71	1.34	16898.24	22271.68	15362.04	29431.75	42315.88	54112.58
2031	9.93	2.00	19.86	2.50	24.83	1.34	17024.35	22581.23				
2032	9.98	2.00	19.96	2.50	24.96	1.34	17148.78	22887.15				
2033	10.03	2.00	20.06	2.50	25.08	1.34	17271.55	23189.47				
2034	10.08	2.00	20.16	2.50	25.21	1.34	17392.68	23488.21				
2035	10.13	2.00	20.27	2.50	25.33	1.34	17512.18	23783.40				

Med (2)

NPV of Alternative Fuel Savings				Cost Effectiveness Factor Adv. Diesel					Cost Effectiveness Factor Alt. Fuels				
Payback Periods (years)				Payback Periods (years)				Tech	Payback Periods (years)				
1	2	3	4	1	2	3	4	Cost	1	2	3	4	
-27517.39	-49829.62	-71340.14	-91123.10	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.00
-24543.46	-48205.02	-69966.28	-88901.44	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-26027.72	-49965.10	-70793.78	-75651.22	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-26331.12	-49242.66	-54585.85	-54896.37	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-25202.69	-31080.20	-31421.77	-29329.63	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-6465.26	-6840.99	-4539.63	-981.60	0.00	0.00	0.00	0.00	100000	0.00	0.00	0.00	0.00	100.0
-413.30	2118.19	6032.03	11869.34	0.00	0.00	0.00	-0.40	100000	0.00	0.00	0.00	0.00	100.0
2784.64	7089.86	13510.90	21004.23	0.00	0.00	-0.52	-1.08	100000	0.00	0.00	0.00	0.00	100.0
4735.74	11798.89	20041.54	28850.25	0.00	-0.44	-1.20	-1.90	100000	0.00	0.00	0.00	0.00	100.0
7769.46	16836.38	26525.96	37091.01	-0.07	-1.15	-2.15	-3.11	100000	0.00	0.00	0.00	0.00	99.3
9973.61	20632.15	32253.70	43725.85	-0.70	-2.27	-3.77	-5.14	100000	0.00	0.00	0.00	0.00	89.9
11724.39	24508.10	37127.46	49355.52	-0.82	-2.55	-4.14	-5.58	100000	0.00	0.00	0.00	0.00	87.2
14062.07	27943.37	41394.23	54494.84	-1.01	-2.85	-4.53	-6.07	100000	0.00	0.00	0.00	0.00	82.6
15269.43	30065.38	44476.05	57722.99	-1.14	-3.10	-4.89	-6.53	100000	0.00	0.00	0.00	0.00	78.7
16275.54	32127.27	46698.91	59850.14	-1.28	-3.38	-5.29	-7.02	100000	0.00	0.00	0.00	0.00	73.9
17436.90	33465.70	47932.05	61129.62	-1.46	-3.70	-5.73	-7.56	100000	0.00	0.00	0.00	0.00	66.9
17631.68	33544.66	48061.98	61136.20	-1.64	-4.03	-6.19	-8.14	100000	0.00	0.00	0.00	0.00	58.2
17504.28	33473.33	47854.97	61026.09	-1.83	-4.39	-6.70	-8.80	100000	0.00	0.00	0.00	0.00	48.0
17565.96	33385.75	47873.99	61004.88	-2.06	-4.81	-7.31	-9.57	100000	0.00	0.00	0.00	0.00	31.9
17401.78	33338.83	47782.82	60869.36	-2.30	-5.31	-8.02	-10.48	100000	0.00	0.00	0.00	0.00	10.0
17530.76	33419.15	47814.33	60946.09	-2.64	-5.92	-8.89	-11.59	100000	0.00	0.00	0.00	0.00	-29.4
17477.22	33311.93	47756.86	60805.96	-2.81	-6.24	-9.37	-12.18	100000	0.00	0.00	0.00	0.00	-55.3
17418.18	33307.60	47661.61	60762.83	-2.99	-6.62	-9.89	-12.86	100000	0.00	0.00	0.00	0.00	-89.5
17478.37	33267.77	47679.11	60988.20	-3.22	-7.03	-10.49	-13.66	100000	0.00	0.00	0.00	0.00	-140.6
17368.34	33220.82	47860.82	61375.38	-3.45	-7.49	-11.20	-14.59	100000	0.00	0.00	0.00	0.00	-205.4
17437.72	33541.72	48407.75	62125.42	-3.74	-8.09	-12.07	-15.71	100000	0.00	0.00	0.00	0.00	-311.7
17714.40	34067.03	49156.46	63074.89	-4.12	-8.81	-13.11	-17.04	100000	0.00	0.00	0.00	0.00	-505.6
17987.89	34586.27	49896.54	64013.37	-4.56	-9.64	-14.30	-18.57	100000	0.00	0.00	0.00	0.00	-842.1
18258.22	35099.51	50628.02	64968.98	-5.06	-10.62	-15.70	-20.36	100000	0.00	0.00	0.00	0.00	-1472.3
18525.42	35606.78	51381.84	65944.34	-5.66	-11.77	-17.36	-22.48	100000	0.00	0.00	0.00	0.00	-2772.5
18789.50	36142.06	52160.81	66942.30	-6.38	-13.15	-19.35	-25.04	100000	0.00	0.00	0.00	0.00	-5805.7
19087.81	36708.44	52968.07	67966.01	-6.44	-13.27	-19.52	-25.24	100000	0.00	0.00	0.00	0.00	-6179.2
19382.69	37268.29	53766.01	68977.87	-6.50	-13.38	-19.68	-25.45	100000	0.00	0.00	0.00	0.00	-6571.0
19674.16	37821.66	54554.70	69977.99	-6.56	-13.49	-19.84	-25.66	100000	0.00	0.00	0.00	0.00	-6981.5
19962.25	38368.60	55334.21	70966.45	-6.62	-13.61	-20.00	-25.86	100000	0.00	0.00	0.00	0.00	-7411.5
20246.98	38909.16	56104.62	71943.34	-6.68	-13.72	-20.16	-26.06	100000	0.00	0.00	0.00	0.00	-7861.3

Med (3)

Tech. Adoption Factor Adv. Diesel								Tech. Adoption Factor Alt. Fuels						
Payback Periods (years)								Payback Periods (years)						
1		2		3		4		1		2		3		4
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	100.0	100.0	95.0	95.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	100.0	100.0	93.2	93.2	80.5	80.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
100.0	94.5	94.5	76.9	76.9	43.2	43.2	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
99.3	78.4	78.4	23.8	23.8	-113.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
89.9	13.0	13.0	-322.5	1.0	-1588.7	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
87.2	-18.5	1.0	-516.4	1.0	-2545.1	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
82.6	-62.7	1.0	-813.7	1.0	-4202.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
78.7	-111.0	1.0	-1219.7	1.0	-6718.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
73.9	-183.8	1.0	-1878.6	1.0	-11045.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
66.9	-296.4	1.0	-2964.5	1.0	-19181.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
58.2	-452.2	1.0	-4786.5	1.0	-34284.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
48.0	-695.7	1.0	-8000.8	1.0	-66177.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
31.9	-1114.1	1.0	-14854.1	1.0	-143753.8	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
10.0	-1906.2	1.0	-30370.0	1.0	-354775.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-3618.6	1.0	-72583.5	1.0	-1076988.3	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-5040.5	1.0	-116695.8	1.0	-1952118.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-7371.6	1.0	-196727.5	1.0	-3832033.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-11187.8	1.0	-358555.6	1.0	-8521342.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-17835.0	1.0	-727566.4	1.0	-21622850.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-32379.5	1.0	-1737833.4	1.0	-66521400.5	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-66916.8	1.0	-4918477.1	1.0	-251336958.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-154300.6	1.0	-16311365.0	1.0	-1162858457.9	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-408222.2	1.0	-65949471.1	1.0	-6971250963.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-1286955.5	1.0	-345556399.1	1.0	-58150120847.2	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-5140337.8	1.0	-2538043738.8	1.0	-745750918714.0	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-5773453.1	1.0	-2994663628.5	1.0	-919704851360.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-6474786.9	1.0	-3525845693.9	1.0	-1131142380474.8	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-7250474.7	1.0	-4142403269.6	1.0	-1387425697821.6	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-8107067.1	1.0	-4856492592.8	1.0	-1697209043686.4	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1.0	-9051543.6	1.0	-5681745483.2	1.0	-2070634752658.5	1.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Med (4)

Market Penetration Advanced Diesel						Market Penetration Alternative Fuels					
16.4%	**61.7%**	**15.5%**	**6.4%**			**16.4%**	**61.7%**	**15.5%**	**6.4%**		
Payback Periods (years)				Final	Final	Payback Periods (years)				Final	Final
1	2	3	4	Step 1	Step 2	1	2	3	4	Step 1	Step 2
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	2.3%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	3.0%	9.8%	1.1%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	2.5%	12.5%	50.9%	6.7%	6.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.1%	11.3%	75.7%	99.8%	25.3%	25.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4.3%	87.9%	99.9%	100.0%	76.8%	76.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.6%	99.4%	100.0%	100.0%	84.1%	84.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
8.4%	99.7%	100.0%	100.0%	84.8%	84.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
11.1%	99.8%	100.0%	100.0%	85.3%	85.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
15.0%	99.9%	100.0%	100.0%	86.0%	86.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
21.7%	99.9%	100.0%	100.0%	87.1%	87.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
31.5%	100.0%	100.0%	100.0%	88.8%	88.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
44.5%	100.0%	100.0%	100.0%	90.9%	90.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
65.7%	100.0%	100.0%	100.0%	94.4%	94.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
90.9%	100.0%	100.0%	100.0%	98.5%	98.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.5%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.6%	100.0%	100.0%	100.0%	99.9%	99.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.7%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.8%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
99.9%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100.0%	100.0%	100.0%	100.0%	100.0%	#####	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Med (5)

Classes 3-6 Market Penetration by Average Annual VMT - Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.5%	0.7%	1.1%	0.0%
0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	1.0%	2.5%	3.9%	6.7%	0.0%
0.0%	0.0%	0.0%	0.3%	0.6%	1.5%	3.5%	6.6%	11.6%	16.8%	25.3%	0.0%
0.0%	0.0%	0.3%	1.6%	4.9%	7.5%	18.6%	29.8%	39.2%	53.0%	76.8%	0.2%
0.0%	0.0%	0.3%	2.0%	6.7%	10.5%	23.9%	35.6%	48.5%	68.0%	84.1%	0.2%
0.0%	0.0%	0.4%	2.6%	9.4%	14.4%	30.7%	42.7%	61.6%	84.3%	84.8%	0.3%
0.0%	0.0%	0.5%	3.3%	12.4%	17.6%	35.4%	50.7%	74.0%	84.3%	85.3%	0.4%
0.0%	0.0%	0.6%	4.3%	15.9%	21.8%	41.0%	62.0%	84.0%	84.8%	86.0%	0.5%
0.0%	0.1%	1.4%	5.7%	19.7%	27.4%	49.7%	76.4%	84.5%	85.4%	87.1%	0.6%
0.0%	0.1%	1.7%	7.7%	24.6%	33.6%	60.6%	84.1%	85.0%	86.3%	88.8%	0.8%
0.0%	0.1%	2.1%	10.5%	30.9%	38.6%	74.4%	84.6%	85.7%	87.4%	90.9%	1.0%
0.0%	0.1%	2.8%	14.6%	36.7%	46.6%	84.1%	85.2%	86.7%	89.3%	94.4%	1.2%
0.0%	0.3%	3.8%	19.0%	44.6%	59.4%	84.7%	86.0%	88.3%	92.1%	98.5%	1.6%
0.0%	0.4%	5.7%	25.8%	58.3%	78.0%	85.5%	87.6%	91.4%	96.9%	99.9%	2.1%
0.0%	0.5%	7.0%	30.1%	67.0%	84.0%	86.0%	88.7%	93.5%	99.4%	99.9%	2.4%
0.0%	0.5%	8.7%	34.3%	77.3%	84.4%	86.7%	90.2%	95.9%	99.9%	#####	2.6%
0.0%	0.6%	11.1%	38.2%	84.1%	84.7%	87.7%	92.4%	98.9%	99.9%	#####	2.8%
0.0%	1.4%	14.3%	43.7%	84.4%	85.2%	89.0%	94.9%	99.9%	100.0%	#####	3.2%
0.0%	1.7%	17.9%	52.8%	84.9%	85.8%	91.2%	98.3%	99.9%	100.0%	#####	3.6%
0.0%	2.3%	22.8%	66.6%	85.6%	86.9%	94.6%	99.9%	100.0%	100.0%	#####	4.2%
0.0%	3.0%	30.0%	83.3%	86.6%	88.7%	99.0%	99.9%	100.0%	100.0%	#####	5.0%
0.0%	4.3%	36.6%	84.5%	88.4%	91.7%	99.9%	100.0%	100.0%	100.0%	#####	5.5%
0.0%	6.5%	46.0%	85.2%	91.5%	96.3%	100.0%	100.0%	100.0%	100.0%	#####	6.2%
0.1%	10.3%	62.3%	86.3%	96.4%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.4%
0.1%	10.7%	63.9%	86.4%	96.9%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.5%
0.1%	11.1%	65.4%	86.6%	97.3%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.7%
0.1%	11.5%	67.0%	86.7%	97.7%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.8%
0.1%	11.8%	68.5%	86.8%	98.2%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	7.9%
0.1%	12.2%	70.0%	87.0%	98.6%	99.9%	100.0%	100.0%	100.0%	100.0%	#####	8.0%

Med (6)

Classes 3-6 Market Penetration by Average Annual VMT - Non-Centrally Refueled Advanced Diesels											
(thousands of miles)											Final
0-19.9	20-39.9	40-59.9	60-79.9	80-99.9	100-119.9	120-139.9	140-159.9	160-179.9	180-199.9	200+	Step 3
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.0%
0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.5%	0.7%	1.1%	0.0%
0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.6%	1.0%	2.5%	3.9%	6.7%	0.0%
0.0%	0.0%	0.0%	0.3%	0.7%	1.5%	3.5%	6.6%	11.6%	16.8%	25.3%	0.0%
0.0%	0.0%	0.1%	1.9%	5.7%	7.4%	18.6%	29.8%	39.2%	53.0%	76.8%	0.1%
0.0%	0.0%	0.3%	2.5%	8.0%	10.3%	23.9%	35.6%	48.5%	68.0%	84.1%	0.1%
0.0%	0.0%	0.4%	3.2%	11.1%	14.1%	30.7%	42.7%	61.6%	84.3%	84.8%	0.2%
0.0%	0.0%	0.5%	4.2%	14.5%	17.3%	35.4%	50.7%	74.0%	84.3%	85.3%	0.2%
0.0%	0.0%	0.6%	5.5%	17.9%	21.4%	41.0%	62.0%	84.0%	84.8%	86.0%	0.3%
0.0%	0.1%	0.7%	7.5%	22.3%	26.9%	49.7%	76.4%	84.5%	85.4%	87.1%	0.4%
0.0%	0.1%	1.6%	10.1%	27.9%	33.3%	60.6%	84.1%	85.0%	86.3%	88.8%	0.5%
0.0%	0.1%	1.9%	13.6%	34.1%	38.2%	74.4%	84.6%	85.7%	87.4%	90.9%	0.7%
0.0%	0.3%	2.5%	17.7%	39.9%	45.9%	84.1%	85.2%	86.7%	89.3%	94.4%	0.8%
0.0%	0.3%	3.4%	23.0%	49.5%	58.4%	84.7%	86.0%	88.3%	92.1%	98.5%	1.1%
0.0%	0.4%	5.0%	31.3%	65.4%	76.8%	85.5%	87.6%	91.4%	96.9%	99.9%	1.5%
0.0%	0.5%	6.1%	34.9%	74.7%	84.0%	86.0%	88.7%	93.5%	99.4%	99.9%	1.6%
0.0%	0.6%	7.7%	38.7%	83.9%	84.3%	86.7%	90.2%	95.9%	99.9%	100.0%	1.8%
0.0%	0.7%	9.8%	44.0%	84.3%	84.7%	87.7%	92.4%	98.9%	99.9%	100.0%	2.0%
0.0%	1.5%	12.8%	51.5%	84.7%	85.1%	89.0%	94.9%	99.9%	100.0%	100.0%	2.4%
0.0%	1.9%	16.3%	63.1%	85.2%	85.8%	91.2%	98.3%	99.9%	100.0%	100.0%	2.8%
0.0%	2.4%	20.8%	78.6%	86.0%	86.8%	94.6%	99.9%	100.0%	100.0%	100.0%	3.3%
0.0%	3.3%	27.3%	84.3%	87.3%	88.6%	99.0%	99.9%	100.0%	100.0%	100.0%	3.9%
0.0%	4.7%	34.7%	84.9%	89.5%	91.5%	99.9%	100.0%	100.0%	100.0%	100.0%	4.6%
0.0%	7.2%	42.7%	85.8%	93.1%	96.0%	100.0%	100.0%	100.0%	100.0%	100.0%	5.5%
0.0%	11.3%	57.2%	87.3%	98.5%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.2%
0.1%	11.8%	58.7%	87.5%	98.9%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.4%
0.1%	12.2%	60.1%	87.6%	99.3%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.5%
0.1%	12.6%	61.6%	87.8%	99.8%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.7%
0.1%	13.0%	63.0%	88.0%	99.9%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	7.8%
0.1%	13.4%	64.5%	88.2%	99.9%	99.9%	100.0%	100.0%	100.0%	100.0%	100.0%	8.0%

New MPG (1)

	Class 3-6				Class 7&8 Type 1				Class 7&8 Type 2			
Year	Conventional	Hybrid	Ethanol	New Average	Conv. Diesel	Adv. Diesel	Ethanol	New Average	Conv. Diesel	Adv. Diesel	Ethanol	New Average
2000	9.00	9.00	9.00	9.00	6.58	6.58	6.58	6.58	6.79	6.79	6.79	6.79
2001	9.02	10.82	10.82	9.02	6.58	7.15	6.58	6.58	6.79	7.37	6.79	6.79
2002	9.04	12.66	12.66	9.04	6.58	7.71	6.58	6.58	6.79	7.96	6.79	6.79
2003	9.06	14.49	14.49	9.06	6.58	8.28	6.58	6.58	6.79	8.54	6.79	6.79
2004	9.08	16.34	16.34	9.08	6.58	8.84	6.58	6.58	6.79	9.13	6.79	6.79
2005	9.10	18.20	18.20	9.11	6.58	9.41	6.58	6.58	6.79	9.71	6.79	6.82
2006	9.12	18.24	19.15	9.14	6.58	9.41	7.04	6.59	6.79	9.71	7.27	6.82
2007	9.14	18.28	20.11	9.16	6.58	9.41	7.50	6.59	6.79	9.71	7.74	6.84
2008	9.16	18.32	21.07	9.19	6.58	9.41	7.96	6.59	6.79	9.71	8.22	6.85
2009	9.18	18.36	22.03	9.21	6.58	9.41	8.42	6.59	6.79	9.71	8.69	6.87
2010	9.20	18.40	23.00	9.25	6.58	9.41	8.88	6.60	6.79	9.71	9.17	6.90
2011	9.22	18.44	23.05	9.28	6.58	9.41	9.55	6.60	6.79	9.71	9.86	6.93
2012	9.24	18.48	23.10	9.31	6.58	9.41	10.23	6.61	6.79	9.71	10.55	6.96
2013	9.26	18.52	23.15	9.36	6.58	9.41	10.90	6.62	6.79	9.71	11.24	7.02
2014	9.28	18.56	23.20	9.40	6.58	9.41	11.57	6.64	6.79	9.71	11.94	7.08
2015	9.30	18.60	23.25	9.47	6.58	9.41	12.24	6.63	6.79	9.71	12.63	7.19
2016	9.32	18.64	23.30	9.51	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2017	9.34	18.68	23.35	9.55	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2018	9.36	18.72	23.40	9.59	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2019	9.38	18.76	23.45	9.65	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2020	9.40	18.80	23.51	9.71	6.58	9.41	12.24	6.66	6.79	9.71	12.63	7.18
2021	9.45	18.90	23.62	9.82	6.58	9.41	12.24	6.69	6.79	9.71	12.63	7.31
2022	9.50	18.99	23.74	9.94	6.58	9.41	12.24	6.74	6.79	9.71	12.63	7.50
2023	9.54	19.09	23.86	10.05	6.58	9.41	12.24	6.79	6.79	9.71	12.63	7.67
2024	9.59	19.18	23.98	10.19	6.58	9.41	12.24	6.87	6.79	9.71	12.63	7.92
2025	9.64	19.28	24.10	10.40	6.58	9.41	12.24	6.97	6.79	9.71	12.63	8.13
2026	9.69	19.38	24.22	10.47	6.58	9.41	12.24	6.98	6.79	9.71	12.63	8.15
2027	9.74	19.47	24.34	10.54	6.58	9.41	12.24	6.98	6.79	9.71	12.63	8.16
2028	9.78	19.57	24.46	10.60	6.58	9.41	12.24	6.99	6.79	9.71	12.63	8.17
2029	9.83	19.67	24.58	10.67	6.58	9.41	12.24	7.00	6.79	9.71	12.63	8.18
2030	9.88	19.77	24.71	10.74	6.58	9.41	12.24	7.00	6.79	9.71	12.63	8.19

New MPG (2)

	Class 7&8 Type 3				Class 7&8			
Year	Conv. Diesel	Adv. Diesel	Ethanol	New Average	Conv. Diesel	Adv. Dsl	Ethanol	New Average
2000	7.00	7.00	7.00	7.00	6.87	6.87	6.87	6.87
2001	7.00	7.60	7.00	7.00	6.87	7.46	6.87	6.87
2002	7.00	8.20	7.00	7.00	6.87	8.06	6.87	6.87
2003	7.00	8.81	7.00	7.00	6.87	8.65	6.87	6.87
2004	7.00	9.41	7.00	7.00	6.87	9.24	6.87	6.87
2005	7.00	9.94	7.00	7.05	6.87	9.79	6.87	6.91
2006	7.00	10.01	7.49	7.07	6.87	9.83	7.35	6.92
2007	7.00	10.01	7.98	7.09	6.87	9.83	7.84	6.94
2008	7.00	10.01	8.47	7.12	6.87	9.83	8.32	6.96
2009	7.00	10.01	8.96	7.15	6.87	9.83	8.80	6.98
2010	7.00	10.01	9.45	7.20	6.87	9.83	9.28	7.01
2011	7.00	10.01	10.16	7.26	6.87	9.83	9.98	7.06
2012	7.00	10.01	10.88	7.32	6.87	9.83	10.68	7.10
2013	7.00	10.01	11.59	7.40	6.87	9.83	11.38	7.16
2014	7.00	10.01	12.31	7.50	6.87	9.83	12.08	7.24
2015	7.00	10.01	13.02	7.64	6.87	9.83	12.79	7.34
2016	7.00	10.01	13.02	7.63	6.87	9.83	12.79	7.34
2017	7.00	10.01	13.02	7.63	6.87	9.83	12.79	7.34
2018	7.00	10.01	13.02	7.63	6.87	9.83	12.79	7.33
2019	7.00	10.01	13.02	7.63	6.87	9.83	12.79	7.33
2020	7.00	10.01	13.02	7.64	6.87	9.83	12.79	7.34
2021	7.00	10.01	13.02	7.81	6.87	9.83	12.79	7.47
2022	7.00	10.01	13.02	8.02	6.87	9.83	12.79	7.64
2023	7.00	10.01	13.02	8.29	6.87	9.83	12.79	7.84
2024	7.00	10.01	13.02	8.55	6.87	9.83	12.79	8.05
2025	7.00	10.01	13.02	8.75	6.87	9.83	12.79	8.23
2026	7.00	10.01	13.02	8.79	6.87	9.83	12.79	8.26
2027	7.00	10.01	13.02	8.81	6.87	9.83	12.79	8.28
2028	7.00	10.01	13.02	8.83	6.87	9.83	12.79	8.29
2029	7.00	10.01	13.02	8.85	6.87	9.83	12.79	8.30
2030	7.00	10.01	13.02	8.86	6.87	9.83	12.79	8.31

Market Penetration

Market Penetration of Advanced Diesels and Alternative Fuels in Heavy Vehicles

	Class 7-8 Type 1		Class 7-8 Type 2		Class 7-8 Type 3		CLASS 7-8 Final		CLASS 3-6 Final	
Year	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced	Current	Enhanced
2000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2001	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2002	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2003	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2004	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2005	0.2%	0.0%	1.2%	0.0%	2.4%	0.0%	1.8%	0.0%	0.3%	0.0%
2006	0.3%	0.0%	1.7%	0.0%	3.3%	0.0%	2.4%	0.0%	0.4%	0.0%
2007	0.4%	0.0%	2.3%	0.0%	4.4%	0.0%	3.2%	0.0%	0.5%	0.0%
2008	0.5%	0.0%	3.0%	0.0%	5.6%	0.0%	4.1%	0.0%	0.6%	0.0%
2009	0.7%	0.0%	3.9%	0.0%	7.1%	0.0%	5.2%	0.0%	0.8%	0.0%
2010	0.9%	0.0%	5.1%	0.0%	9.1%	0.0%	6.7%	0.0%	1.0%	0.0%
2011	1.2%	0.0%	6.6%	0.0%	11.8%	0.0%	8.7%	0.0%	1.3%	0.0%
2012	1.6%	0.0%	8.3%	0.0%	14.5%	0.0%	10.8%	0.0%	1.6%	0.0%
2013	2.2%	0.0%	10.7%	0.0%	17.9%	0.0%	13.5%	0.0%	2.0%	0.0%
2014	2.9%	0.0%	13.8%	0.0%	22.4%	0.0%	17.0%	0.0%	2.7%	0.0%
2015	2.6%	0.0%	18.4%	0.0%	27.8%	0.0%	21.2%	0.0%	3.6%	0.0%
2016	4.2%	0.0%	18.1%	0.0%	27.6%	0.0%	21.3%	0.0%	4.0%	0.0%
2017	4.1%	0.0%	18.0%	0.0%	27.5%	0.0%	21.2%	0.0%	4.4%	0.0%
2018	4.1%	0.0%	17.9%	0.0%	27.4%	0.0%	21.1%	0.0%	4.8%	0.0%
2019	4.1%	0.0%	17.9%	0.0%	27.3%	0.0%	21.1%	0.0%	5.6%	0.0%
2020	4.2%	0.0%	18.2%	0.0%	27.7%	0.0%	21.4%	0.0%	6.4%	0.0%
2021	5.6%	0.0%	23.7%	0.0%	34.6%	0.0%	27.0%	0.0%	7.5%	0.0%
2022	7.7%	0.0%	31.3%	0.0%	42.4%	0.0%	33.7%	0.0%	8.9%	0.0%
2023	10.3%	0.0%	38.2%	0.0%	51.7%	0.0%	41.3%	0.0%	10.1%	0.0%
2024	14.0%	0.0%	47.4%	0.0%	60.3%	0.0%	49.1%	0.0%	11.7%	0.0%
2025	18.6%	0.0%	54.7%	0.0%	66.5%	0.0%	55.3%	0.0%	14.6%	0.0%
2026	18.9%	0.0%	55.3%	0.0%	67.8%	0.0%	56.3%	0.0%	14.9%	0.0%
2027	19.2%	0.0%	55.8%	0.0%	68.4%	0.0%	56.8%	0.0%	15.2%	0.0%
2028	19.5%	0.0%	56.1%	0.0%	69.0%	0.0%	57.2%	0.0%	15.4%	0.0%
2029	19.8%	0.0%	56.4%	0.0%	69.5%	0.0%	57.7%	0.0%	15.7%	0.0%
2030	20.1%	0.0%	56.7%	0.0%	69.8%	0.0%	58.0%	0.0%	16.0%	0.0%

LIGHT VEHICLE ATTRIBUTES FOR GPRA 2004 BENEFITS MODELING

By Elyse Steiner, NREL

The vehicle attributes for the car and light truck technologies were based on the Office of FreedomCAR and Vehicle Technologies program goals and discussions with transportation program managers. They represent the best estimates available at the time of the modeling (summer of 2002). These attributes have been documented for the past several years and continue to be refined each year, as necessary. The table below contains the attribute values used for the 2004 GPRA transportation program modeling. The values shown in the table are ratios relative to a conventional ICE of the same type. Attributes include the following:

- Vehicle Price
- Range
- Maintenance Cost
- Luggage Space
- Acceleration
- Top Speed
- Fuel Economy

There were several technology changes made from the previous year. The higher fuel economy (2X) hybrid electric vehicle was defined as a diesel-fueled HEV. Flex fuel (E-85) and electric vehicles were not modeled in the 2004 version. Also, 2b trucks were separated from other light trucks in the model. Several updates were made to the actual values in the table compared to the previous year. Those values can be found in the 2003 GPRA methodology report on the EERE website (http://www.ott.doe.gov/facts/pdfs/appendix2003.pdf). No methodology report for 2004 has been written.

LDV ATTRIBUTES - Ratio to Conventional

	SMALL CAR					LARGE CAR					MINIVAN				SUV					CARGO (Incl. 2b) TRUCK			
	Market Intro.	---------->			Market Mature	Market Intro.	---------->			Market Mature	Market Intro.	---------->		Market Mature	Market Intro.	---------->			Market Mature	Market Intro.	---------->		Market Mature
Advanced Diesel	**2004**	**2010**				**2005**	**2010**				**2006**	**2010**			**2004**	**2010**				**2003**	**2008**		
Vehicle Price	1.07	1.07				1.07	1.05				1.08	1.07			1.08	1.07				1.10	1.07		
Range	1.20	1.20				1.20	1.20				1.20	1.20			1.20	1.20				1.20	1.20		
Maintenance Cost	1.00	1.00				1.00	1.00				1.00	1.00			1.00	1.00				1.00	1.00		
Acceleration	1.10	1.10				1.10	1.10				1.10	1.10			1.10	1.10				1.10	1.10		
Top Speed	0.85	0.85				0.80	0.80				0.80	0.80			1.00	1.00				1.00	1.00		
Luggage Space	1.00	1.00				1.00	1.00				1.00	1.00			1.00	1.00				1.00	1.00		
Fuel Economy	1.40	1.40				1.40	1.40				1.40	1.40			1.40	1.40				1.40	1.40		
CNG (dedicated)	**2006**	**2015**				**2007**	**2015**				**2008**	**2015**			**2008**	**2015**				**2007**	**2015**		
Vehicle Price	1.08	1.08				1.04	1.04				1.05	1.05			1.05	1.05				1.10	1.10		
Range	0.66	0.66				0.75	0.75				0.75	0.75			0.75	0.75				0.75	0.75		
Maintenance Cost	0.90	0.90				0.90	0.90				0.90	0.90			0.90	0.90				0.90	0.90		
Acceleration	1.00	1.00				1.00	1.00				1.00	1.00			1.00	1.00				1.00	1.00		
Top Speed	1.00	1.00				1.00	1.00				1.00	1.00			1.00	1.00				1.00	1.00		
Luggage Space	0.75	0.90				0.85	0.90				0.90	1.00			0.90	1.00				1.00	1.00		
Fuel Economy	1.00	1.00				1.00	1.00				1.00	1.00			1.00	1.00				1.00	1.00		
Hybrid (A) - Diesel	**2011**	**2015**	**2025**			**2010**	**2015**	**2025**			**2011**	**2015**	**2025**		**2010**	**2015**	**2025**			**2012**	**2015**	**2025**	
Vehicle Price	1.18	1.12	1.05			1.20	1.15	1.05			1.20	1.15	1.05		1.20	1.15	1.05			1.20	1.15	1.05	
Range	1.00	1.00	1.00			1.00	1.00	1.00			1.00	1.00	1.00		0.90	0.95	0.95			0.90	0.90	0.95	
Maintenance Cost	1.05	1.05	0.98			1.05	1.05	1.00			1.09	1.05	1.00		1.05	1.05	1.00			1.05	1.05	1.00	
Acceleration	0.90	0.90	0.90			1.00	1.00	1.00			0.90	0.90	0.90		0.90	0.90	0.90			1.00	1.00	1.00	
Top Speed	0.90	0.90	0.90			0.90	0.90	0.90			0.90	0.90	0.90		0.90	0.90	0.90			0.90	0.90	0.90	
Luggage Space	0.95	0.95	0.95			0.95	0.95	0.95			0.90	0.90	1.00		0.90	0.90	0.90			0.80	0.90	0.90	
Fuel Economy	1.50	1.75	2.00			1.50	1.75	2.00			1.50	1.75	2.00		1.50	1.75	2.00			1.50	1.75	2.00	
Hybrid (B)	**2004**	**2010**	**2015**	**2020**	**2030**	**2004**	**2010**	**2015**	**2020**	**2030**	**2004**	**2010**	**2015**	**2020**	**2004**	**2010**	**2015**	**2020**	**2030**	**2006**	**2010**	**2015**	**2020**
Vehicle Price	1.10	1.05	1.03	1.01	1.01	1.10	1.08	1.03	1.01	1.01	1.10	1.08	1.03	1.01	1.10	1.08	1.03	1.01	1.01	1.10	1.08	1.03	1.01
Range	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Maintenance Cost	1.05	1.05	1.05	1.00	0.90	1.05	1.05	1.05	1.00	0.90	1.05	1.05	1.05	1.00	1.05	1.05	1.05	1.00	0.90	1.05	1.05	1.05	0.93
Acceleration	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Top Speed	0.90	0.90	0.90	0.90	0.90	0.75	0.90	0.90	0.90	0.90	0.75	0.90	0.90	0.90	0.80	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Luggage Space	0.95	0.95	0.95	0.95	0.95	0.85	0.95	0.95	0.95	0.95	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.80	0.95	0.95	1.00
Fuel Economy	1.25	1.35	1.45	1.50	1.50	1.25	1.35	1.45	1.50	1.50	1.25	1.35	1.45	1.50	1.25	1.35	1.45	1.50	1.50	1.25	1.35	1.45	1.50
Fuel Cell (hydrogen)	**2018**	**2020**	**2025**	**2030**		**2016**	**2020**	**2025**	**2030**		**2014**	**2020**	**2025**	**2030**	**2012**	**2015**	**2020**	**2025**	**2030**	**2012**	**2020**	**2025**	**2030**
Vehicle Price	1.35	1.30	1.15	1.15		1.40	1.25	1.15	1.15		1.35	1.25	1.15	1.15	1.40	1.35	1.25	1.15	1.15	1.35	1.25	1.15	1.15
Range	0.75	0.75	0.75	0.75		0.90	0.90	0.90	0.90		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Maintenance Cost	1.05	1.05	0.93	0.90		1.05	1.05	0.93	0.90		1.10	1.10	0.95	0.90	1.05	1.05	1.05	0.93	0.90	1.05	1.05	0.93	0.90
Acceleration	1.10	1.10	1.10	1.10		1.00	1.00	1.00	1.00		1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.00	1.00	1.00	1.00
Top Speed	0.90	0.90	0.90	0.90		0.72	0.90	0.90	0.90		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Luggage Space	0.90	0.90	0.90	0.90		0.80	0.90	0.90	0.90		0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.80	0.80	0.85	0.85
Fuel Economy	2.50	2.70	3.00	3.00		2.20	2.50	3.00	3.00		2.00	2.50	3.00	3.00	2.00	2.30	2.50	3.00	3.00	2.00	2.50	3.00	3.00
Fuel Cell (gasoline)						**2010**	**2020**	**2025**	**2030**		**2010**	**2020**	**2030**		**2010**	**2020**	**2030**						
Vehicle Price						1.40	1.35	1.20			1.35	1.30			1.40	1.35							
Range						1.00	1.00	1.00			1.00	1.00			1.00	1.00							
Maintenance Cost						1.05	1.00	0.93	OUT		1.05	1.00	OUT		1.05	1.00	OUT						
Acceleration						1.00	1.00	1.00	OF		1.00	1.00	OF		1.00	1.00	OF						
Top Speed						1.00	1.00	1.00	MARKET		1.00	1.00	MARKET		1.00	1.00	MARKET						
Luggage Space						0.90	0.90	0.90			0.90	0.90			0.90	0.90							
Fuel Economy						1.50	1.80	2.00			1.40	1.80			1.40	1.80							

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14. ABSTRACT *(Maximum 200 Words)*

The Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy (DOE) leads the Federal Government's efforts to provide reliable, affordable, and environmentally sound energy for America, through its research, development, and deployment (RD&D) programs. EERE invests in high-risk, high-value research and development (R&D) that, conducted in partnership with the private sector and other government agencies, accelerates the development and facilitates the deployment of advanced clean energy technologies and practices. The RD&D activities of EERE are designed to improve the nation's readiness to address future energy needs. This document summarizes the results of the benefits analysis of EERE's programs, as described in the FY 2004 Budget Request. EERE is adopting a benefits framework developed by the National Research Council (NRC) to represent the various types of benefits resulting from the energy efficiency technology improvements and renewable energy technology development prompted by EERE programs. Specifically, EERE's benefits analysis focuses on three main categories of energy-linked benefits—economic, environmental, and security. These measures are not a complete representation of the benefits or market roles of efficiency and renewable technologies, but provide an indication of the range of benefits provided.

15. SUBJECT TERMS
Government Performance and Results Act; GPRA 04; benefits estimates; portfolio benefits; program benefits; benefits analysis; biomass program; building technologies program; distributed energy resources program; federal energy management program; geothermal technologies program; hydrogen, fuel cells, and infrastructure technologies program; industrial technologies program; solar energy technologies program; vehicle technologies program; weatherization and intergovernmental program; wind and hydropower technologies program.

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